CENTRAL ELECTRICITY AUTHORITY
NOTIFICATION

New Delhi, the , 2009

No. CEA/TETD/MP/R/01 In exercise of the powers conferred by clause (b) of Section 73 read with sub-section (2) of Section 177 of the Electricity Act 2003, the Central Electricity Authority hereby makes the following regulations namely:

1. Short Title and Commencement

(1) These regulations may be called the "Central Electricity Authority (Construction of Electrical Plants & Electric Lines) Regulations, 2009".

(2) These regulations shall come into force on the date of their publication in the Gazette of India.

2. Definitions

(1) In these regulations, unless the context otherwise requires,

(a) "Act" means the Electricity Act, 2003.

(b) "Authority" means the Central Electricity Authority established under sub-section (2) of Section 70 of the Act.

(c) "Base Load Operation" means operation at Maximum Continuous Rating (MCR) or its high fraction.

(d) "Basic Insulation Level (BIL)" means reference voltage level expressed in peak (crest) voltage with standard 1.2/50 µs lightning impulse wave. Apparatus should be capable of withstanding test wave of basic insulation level or higher.

(e) "Black Start" means the start up of a generating unit or gas turbine or diesel generating set without use of external power following grid failure.

(f) "Boiler Maximum Continuous Rating (BMCR)" means the maximum steam output, the steam generator (boiler) can deliver continuously at rated parameters.

(g) "Break Time" means interval of time between the beginning of the opening of a switching device and the end of the arcing.

(h) "Burden"

- in relation to instrument transformer means the impedance of the secondary circuit. (Note- The burden is usually expressed as the apparent power absorbed by the secondary circuit at a specified power factor at the rated secondary current or voltage).

- in relation to relay means the power absorbed by the circuits of the relay expressed in volt-amperes (on AC) and in watts (on DC) at rated values of current or voltage.

(i) "Cold Start" in relation to steam turbine means start up after a shut down period exceeding 72 hours (turbine metal temperatures below approximately 40% of their full load values).

(j) "Combined Cycle Gas Turbine (CCGT) module" means gas turbine generator(s), associated heat recovery steam generator (s) and steam turbine generator.

(k) "Control Load" in relation to coal or lignite based thermal generating units means the lowest load at which the rated steam temperature can be maintained under auto control system.

(l) "Current Transformer" means an instrument transformer in which the secondary current, in normal conditions of use, is substantially proportional to the primary current and differs in phase from it by an angle which is approximately zero for an appropriate direction of the connections.

(m) "Design Head" means the net head at which peak efficiency of hydraulic turbine is attained while operating at rated output.

(n) "FRLS Cable" means Flame Retardant Low Smoke cable which emits low smoke and does not propagate fire.

(o) "FS Cable" means Fire Survival cable, which maintains circuit integrity during and after fire.

(p) "Gas Turbine" means a machine which converts thermal energy into mechanical work and includes compressor, combustion system and expansion turbine.

(q) "Gross Head" means the difference in elevation between the water levels of the upstream reservoir and the water level in the discharge chamber in case of Pelton turbine and tail race at the exit end of the draft tube in case of Francis and Kaplan turbines.

(r) "Gross Heat Rate" in relation to gas turbine based and diesel engine based thermal generating stations means the external heat energy input required to generate one kWh of electrical energy at generator terminals.

(s) "Gross Turbine Cycle Heat Rate" in relation to coal or lignite based thermal generating station means the external heat energy input to the turbine cycle required to generate one kWh of electrical energy at generator terminals.

(t) "High Heat Value (HHV)" means the heat produced by complete combustion of one kilogram of solid fuel or liquid fuel or one standard cubic meter (Sm^3) of gaseous fuel as determined as per relevant IS.

(u) "Highest System Voltage" means the highest root mean square (r.m.s.) line to line value of voltage which can be sustained under normal operating conditions at any time and at any point in the system. It excludes temporary voltage variation due to fault conditions and the sudden disconnection of the large load.

(v) "Hot Start" in relation to steam turbine means start up after a shut down period of less than 10 hours (turbine metal temperatures approximately 80% of their full load values).

(w) "House Load" means the unit is operating in isolation to the grid and generating electric power to cater to its own auxiliaries.

(x) "Hydraulic Turbine" means a machine which converts the potential energy of water into mechanical work to rotate the generator.

(y) "Hydro-electric Generating Station" means the 'generating station' as defined in the Act for generating electricity by water-power.

(z) "Impedance Earthed Neutral System" means a system whose neutral point(s) is(are) earthed through impedances to limit earth fault currents.

(aa) "Impulse" means a unidirectional wave of voltage or current which, without appreciable oscillations, rises rapidly to a maximum value and falls, usually less rapidly, to zero with small, if any, loops of opposite polarity. The parameters which define a voltage or current impulse are polarity, peak value, front time, and time to half value on the tail.

(bb) "Impulse Withstand Voltage" means peak value of the standard impulse voltage wave which the insulation of an equipment is designed to withstand under specified test conditions.

(cc) "Insulation Co-ordination" means the selection of the dielectric strength of equipment in relation to the voltages which can appear on the system for which the equipment is intended and taking into account the characteristics of the available protective devices.

(dd) "Isolated Neutral System" means a system where the neutral point is not intentionally connected to earth, except for high impedance connections for protection or measurement purposes.

(ee) "Load Cycling" means operation alternating at high and low level of load on a regular basis.

(ff) "Maximum Continuous Rating" or "MCR"

- in relation to coal or lignite based thermal generating units means maximum continuous output at the generator terminals (net of any external excitation power) as guaranteed by the manufacturer at the rated parameters.

- in relation to combined cycle gas turbine module means the sum of maximum continuous output of the Gas Turbine Generator(s) and Steam Turbine Generator measured at the generator terminals (net of any external excitation power) as guaranteed by the manufacturer for design fuel and corresponding to site conditions.

- in relation to diesel generating sets means maximum continuous output at the generator terminals (net of any external excitation power) as guaranteed by the manufacturer for design fuel and corresponding to site conditions.

(gg) "Maximum Net Head" means the net head resulting from the difference in elevations between the maximum head water level and the tailrace level without spillway discharge and with one unit operating at no load speed corresponding to turbine discharge of approximately 5% of rated flow. Under this condition, the hydraulic losses are negligible and may be disregarded.

(hh) "Mesh Voltage" means the maximum touch voltage within a mesh of a ground grid.

(ii) "Minimum Net Head" means the net head resulting from the difference in elevation between the minimum head water level or the minimum draw down level and the maximum tailrace level (all turbines operating at full gate opening). minus losses.

(jj) "Minimum Tail Water Level" for a hydro station means the water level in the discharge chamber in case of Pelton turbine and tail race at the exit end of the draft tube in case of Francis and Kaplan turbines corresponding to a discharge required to run one machine at no load.

(kk) "Motor Control Centre (MCC)" means the switchgear which contains modules for motor supply and its control.

(ll) "Net Head" means the gross head less all hydraulic losses except those pertaining to the turbine but including draft tube exit losses.

(mm) "On Load Tap Changer (OLTC)" means a device provided on high voltage side of transformer, which is used for variation of voltage during charged condition of the transformer.

(nn) "Off Circuit Tap Changer (OCTC)" means a device provided on high voltage side of transformer, which is used for variation of voltage during OFF condition of the transformer.

(oo) "Overhead Line" means any electric line which is placed above the ground and in the open air, but does not include live rails of traction system.

(pp) "Owner" means the company or body corporate or association or body of individuals, whether incorporated or not or artificial juridical person who owns or operates or maintains Electrical Plants and/or Electric Lines.

(qq) "Performance Coal" means the coal of quality for which steam-generator performance is guaranteed by the manufacturer.

(rr) "Power Control Centre (PCC)" means the switchgear which contains modules for power supply to other switchboards, switchgears, distribution boards and its control.

(ss) "Power House" in relation to hydro-electric generating station means the structure which houses turbines, generators, including the associated control valves and/or gates, associated electro-mechanical and control equipment.

(tt) "Pump Turbine" means a hydraulic turbine having a runner capable of running in one direction in generating mode and reverse direction in pumping mode.

(uu) "Pumped Storage Plant" means a system of generating electricity in which the electricity is generated during the peak hours by using water that has been pumped into upper reservoir during off-peak hours from the lower reservoir.

(vv) "Rotational Speed" means the number of rotations or revolutions per unit of time, measured in rotations or revolutions per second or per minute.

(ww) "Runaway Speed" means the speed attained by a hydraulic turbine at full gate opening when the generator is disconnected from the system and the governor is in-operative.

(xx) "Solidly Earthed Neutral System" means a system whose neutral point(s) is (are) earthed directly.

(yy) "Specific Speed" in relation to hydraulic turbine means the speed in rpm at which a given hydraulic turbine would rotate, if reduced homologically in size, so that it would develop 1 metric horse power (i.e. 736 Watts) under 1 metre of head at full gate opening.

(zz) "Station" means either the Thermal Generating Station or Hydro-electric Generating Station depending upon the context.

(aaa) "Steam Turbine" means a machine which converts thermal energy from steam into mechanical work to drive the electrical generator.

(bbb) "Step Potential" means the maximum value of potential difference possible of being shunted by a human body between accessible points on the ground separated by distance of one pace which may be assumed to be one metre.

(ccc) "Sub-critical Unit" in relation to coal or lignite based thermal generating unit means a unit designed for main steam pressure less than the critical pressure (221.2 bars).

(ddd) "Super-critical Unit" in relation to coal or lignite based thermal generating unit means a unit designed for main steam pressure more than the critical pressure (221.2 bars).

(eee) "Surface Power House" in relation to hydro-electric generating station means the Power House in which upper part starting from the generator floor or service bay are above the ground.

(fff) "Surge Arrester" means a device designed to protect electrical apparatus from high transient voltage and to limit the duration and frequently the amplitude of follow-current. The term "Surge Arrester" includes any external series gap which is essential for the proper functioning of the device as installed for service, regardless of whether or not it is supplied as an integral part of the device.

(ggg) "Switchgear" means switching devices and their combination with associated control, measuring, protective and regulating equipment, also assemblies of such devices and equipment with associated interconnections, accessories, enclosures and supporting structures, intended in principle for use in connection with generation, transmission, distribution and conversion of electric power.

(hhh) "Switchyard" means a sub-station associated with a generating station for transforming electricity for further transmission.

(iii) "Synchronous Condenser Mode" refers to that condition of the synchronous machine coupled to the turbine when it is running only with mechanical load and supplying leading or lagging reactive power.

(jjj) "Thermal Generating Station" means the 'generating station' as defined in the Act for generating electricity using fossil fuels such as coal, lignite, gas, liquid fuel or combination of these as its primary source of energy.

(kkk) "Touch Potential" is the potential difference between the object touched and the ground point just below the person touching the object when ground currents are flowing.

(lll) "Transients" means over voltage or over current phenomena prevailing in an electrical system for a short period of the order of a fraction of a second or a few seconds not exceeding five seconds.

(mmm) "Turbine Setting" in relation to hydro-electric generating station means the elevation of distributor centre line or runner centre line.

(nnn) "Two Shift Operation" means operation at MCR or its high fraction for about sixteen hours in a day, unit being shut down for the remaining time.

(ooo) "Under Ground Power House" in relation to hydro-electric generating station means the Power House in which all major components of the turbine-generator sets are underground.

(ppp) "Unit"

- in relation to a coal or lignite based thermal generating station means steam generator with interconnected steam turbine-generator and auxiliaries, operated as one single set or system to generate electric power.

- in relation to a hydro generating station means generator with interconnected turbine and auxiliaries, operated as one single set or system to generate electric power.

(qqq) "Voltage Transformer" means an instrument transformer in which the secondary voltage, in normal conditions of use, is substantially proportional to the primary voltage and differs in phase from it by an angle which is approximately zero for an appropriate direction of the connections.

(rrr) "Warm Start" in relation to steam turbine means start up after a shut down period between 10 hours and 72 hours (turbine metal temperatures between approximately 40% and 80% of their full load values).

(2) Words and expressions used but not defined above shall have the same meaning respectively assigned to them in the Act.

3. Applicability of Regulations

These regulations shall apply to all Electrical Plants and Electric Lines for which order is placed by the Owner after the date of notification of these regulations.

4. Objectives

These regulations are intended to specify the Technical Standards for construction of Electrical Plants and Electric Lines with the objective that all Electrical Plants and Electric Lines to be constructed conform to minimum requirements as laid down hereunder to ensure high level of performance in respect of reliability, availability, efficiency, safety and maintainability over their lifetime.

5. Technical Standards

All Electrical Plants and Electric Lines to be constructed shall conform to the General Requirements stipulated at Regulation 6 below and "The Technical Standards for Construction of Electrical Plants and Electric Lines" as appended with these Regulations at Schedule -I to IV detailed hereunder:

Schedule I: Technical Standards for construction of Thermal Generating Stations

Schedule II: Technical Standards for construction of Hydro-electric Generating Stations

Schedule III: Technical Standards for construction of Sub-stations and Switchyards

Schedule IV: Technical Standards for construction of Electric Lines

6. General Requirements

(1) The Electrical Plants and Electric Lines shall be constructed considering prudent engineering practices and optimal utilization of resources. These shall be complete and include all the equipment and systems necessary to ensure high level of reliability, availability, efficiency, safety and maintainability over their lifetime.

(2) The Electrical Plants and Electric Lines shall be suitable for full range of ambient and other environmental conditions as prevailing at site.

(3) The various parts or components or assemblies of equipment and systems shall be of proven materials with well established physical and chemical properties appropriate to the service as intended.

(4) All equipment and systems installed shall comply with latest statutes, regulations and safety codes, as applicable.

(5) The Electrical Plants and Electric Lines shall be designed to comply with the requirements stipulated in

(a) Central Electricity Authority (Installation and Operation of Meters) Regulations, 2006.

(b) Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007.

(c) Central Electricity Authority (Measures relating to Safety and Electricity Supply), Regulations as and when these are notified by the Authority.

(d) Central Electricity Authority (Safety Requirements for Construction, Operation and Maintenance of Electrical Plants and Electric Lines) Regulations as and when these are notified by the Authority.

(e) Central Electricity Authority (Grid Standards) Regulations as and when these are notified by the Authority.

(f) Indian Electricity Grid Code issued by Central Electricity Regulatory Commission (CERC) and

(g) Applicable State Grid Code issued by appropriate Regulatory Commission.

(6) The design, construction and testing of all equipment, facilities, components and systems shall be in accordance with latest version of relevant standards and codes issued by Bureau of Indian Standards (BIS) and/or reputed international standards and codes. A non-exhaustive list of reputed international standards is given below:

(a) American National Standards Institute (ANSI)

(b) American Petroleum Institute (API)

(c) American Society of Mechanical Engineers (ASME)

(d) American Society of Testing and Materials (ASTM)

(e) American Water Works Association (AWWA)

(f) American Welding Society (AWS)

(g) British Standards (BS)

(h) Deutsches Institut fur Normung (DIN), Germany

(i) Gosstandart of Russia (GOST) standards

(j) Heat Exchange Institute (HEI), USA

(k) Hydraulic Institute Standards (HIS), USA

(l) International Electro-technical Commission (IEC)

(m) Institute of Electrical and Electronics Engineers (IEEE)

(n) International Organisation for Standardisation (ISO)

(o) Japanese Industrial Standards (JIS)

(p) National Electric Code (NEC), USA

(q) National Electrical Manufacturers Association (NEMA), USA

(r) National Fire Protection Association (NFPA), USA

(s) Occupational Safety & Health Administration (OSHA)

(t) Tubular Exchanger Manufacturers Association (TEMA), USA

(u) VDE association for Electrical, Electronic and Information Technologies (VDE), Germany

Other international Standards, equivalent or superior to the above Standards can also be adopted. However, in the event of any conflict between the requirements of the international standards or codes and the requirements of the BIS standards or codes, the latter shall prevail.

(7) All materials, components and equipment shall be tested at all stages of procurement, manufacturing, erection, commissioning as per comprehensive Quality Assurance Programme to be agreed mutually between the Owner and the equipment supplier.

(8) The SI or MKS system of units shall be used for design, drawings, diagrams, instruments etc.

(9) The Owner shall retain at the site and make available the following documents:

(a) As-built drawings including, but not limited to the civil and architectural works;

(b) Copies of the project design memorandum, technical description, data sheets, operating manuals and manufacturer's warranties for all major items and/ or equipment;

(c) Copies of the results of all tests performed and

(d) Technical documents relating to the design, engineering and construction of the electrical plant and/or electric line.

(10) The Owner shall implement information technology based system for effective project monitoring so as to facilitate timely execution of the projects of capacity equal to or higher than capacity indicated below :

Thermal generating station:	250 MW
Hydro generating station:	100 MW
Transmission lines and sub-stations:	220 kV and above

The system shall monitor status of ordering, engineering, supplies and physical progress of site activities and help in identifying the bottlenecks in achieving the scheduled completion of the project. The system shall be web based and shall have connectivity with major suppliers/contractors and shall also have provision for connection to centralized project monitoring system of the Authority.

7. Power to Remove Difficulties

If any difficulty arises in giving effect to the provisions of these Regulations, the Authority may, by an order, make such provisions as may be necessary for removing the difficulty.

SCHEDULE- I

TECHNICAL STANDARDS FOR CONSTRUCTION OF THERMAL GENERATING STATIONS

8. Preliminary

This Schedule stipulates the minimum technical requirements for construction of Thermal Generating Stations of various types in following four parts:

Part- A: Common to all types of Thermal Generating Stations

Part- B: Coal or lignite based Thermal Generating Stations

Part- C: Gas Turbine based Thermal Generating Stations

Part- D: Diesel Engine based Thermal Generating Stations

PART- A: COMMON TO ALL TYPES OF THERMAL GENERATING STATIONS

9. General Technical Requirements

(1) The coal or lignite based thermal generating stations shall be designed to give life of not less than twenty five (25) years. Gas turbine based Stations and diesel engine based Stations shall be designed for life not less than fifteen (15) years.

(2) The Station shall comply with all applicable environmental stipulations of Ministry of Environment and Forests (MOE&F) in regard to ambient air quality, gaseous emissions, liquid effluent discharges, solid waste disposal and any other stipulation of the Central Pollution Control Board (CPCB) and State Pollution Control Board (SPCB) in this regard.

(3) **Noise level**

(a) Noise level at the Station boundary shall not exceed the Ambient Air Quality Standard in respect of noise as notified by MOE&F and any other stipulation of the CPCB and SPCB in this regard.

(b) Noise level for the continuously operating equipment shall not be more than 85 dBA at a distance of 1 metre and at a height of 1.5 metre from any equipment except in case of Turbine – Generator for which noise level shall not exceed 90 dBA. For short term exposure, noise levels shall not exceed the limits as stipulated in the Occupational Safety & Health Administration (OSHA) Standard.

(c) Equipment/ machines shall be provided with acoustic enclosures, wherever required so as not to exceed the permissible noise limits.

(4) Areas where a potential flammable atmosphere may exist shall be classified in accordance with the provisions of latest version of relevant IS. Certified equipment shall be used in the designated hazardous areas. To the extent practicable, equipment requiring operator's attention and/or electrical equipment shall not be installed in hazardous areas.

(5) All the equipment and surfaces (excluding coal or lignite mills, pulverized fuel pipes and electrical equipment) having skin temperature more than 60^0C shall be provided with required insulation along with cladding. The insulating materials, accessories and protective covering shall be non-sulphurous, incombustible, low chloride content, chemically rot proof, non-hygroscopic and shall withstand continuously and without deterioration the maximum temperature to which they will be subjected as per duty conditions. Insulation or finishing materials containing asbestos in any form shall not be used.

(6) Auxiliaries involving large power consumption such as motor driven BFPs, ID fans (radial type) shall be provided with variable frequency drive (VFD) or hydraulic coupling to optimize power consumption.

10. Site Selection and Layout Considerations

(1) **Site selection**

The following criteria shall be considered for selection of site for thermal generating stations:

(a) Availability of adequate land for the Station

(b) Avoidance of proximity to geological faults, high flood zone of rivers or the high tide zones of sea / backwaters

(c) Siting criteria prescribed by MOE&F

(d) Availability of required water

(e) Feasibility of rail, road or other linkages for transportation of fuel and equipment to the site

(f) Feasibility of power evacuation

(2) **Layout considerations**

General layout of the Station shall be developed considering space optimization, functional requirements, future extensions (if envisaged) and provision of space requirements during construction stage. Following minimum layout requirements shall be complied with as may be applicable for coal or lignite and/or gas turbine based Stations:

(a) The layout of the Station shall be compact so as to optimise use of land, materials and minimise system losses.

(b) Adequate provision shall be made in regard to space and access in order to carry out the maintenance of various equipment. Adequate maintenance facilities shall be provided as required, for assembly, disassembly and handling during maintenance of various equipment.

(c) Due consideration shall be given for the wind direction while deciding on the relative location of the following:

(i) Cooling tower and switchyard to minimize the moisture drift towards the switchyard.

(ii) Chimney and ash disposal area with respect to township and adjoining habitation areas (applicable for coal or lignite based generating stations)

(d) Adequate space shall be provided for unloading and maintenance purposes in Turbine - Generator (TG) area. Requisite lay down area shall be provided for each unit on TG floor and same shall be approachable with electric overhead travelling (EOT) crane.

In case of coal or lignite based generating stations, two transverse bays shall be provided in TG area at ground level at one end of the building for unloading and maintenance purposes. For Stations with multiple units, adequate space shall be provided to meet the requirement for simultaneous maintenance of two units.

(e) Coal or lignite mill- bunker bay shall preferably be located either on sides or rear of the steam generator to avoid the dust nuisance. In case bunker bay is located adjacent to TG area, suitable isolation arrangement shall be provided to avoid entry of coal/lignite dust in TG area.

(f) Adequate fire escape staircases shall be provided in TG building with fire doors at each landing.

(g) For coal or lignite based generating stations, interconnecting walkways between TG building and steam generator shall be provided at TG operating floor level and at deaerator floor level. Walkways at various levels shall also be provided for interconnection between steam generator and mill-bunker bay.

(h) Minimum one (1) no. of staircase, for each unit/ module, and minimum one (1) no. elevator shall be provided in the TG building. In addition, at least the following elevators shall also be provided for coal or lignite based generating stations:

(i) One passenger-cum goods elevator for each steam-generator

(ii) One elevator for chimney with suitable landings

(i) Adequate number of permanent stores and open paved yard shall be provided as per requirement of the Station for storage of spares and materials etc.

(j) Provision of adequate space, as per stipulation of MOE&F, shall be made for future installation of flue gas desulphurization plant.

PART- B: COAL OR LIGNITE BASED THERMAL GENERATING STATIONS

11. Operating Capabilities of a Unit in the Station

(1) The unit shall give MCR output under the following conditions:

- Maximum cooling water temperature at site
- Worst fuel quality stipulated for the unit
- Grid frequency variation of -5% to +3% (47.5 Hz to 51.5 Hz)

(2) The unit shall be capable of base load operation. However, the unit shall also be capable of regular load cycling and two-shift operation. The steam turbine shall be designed for a minimum of 4000 hot starts, 1000 warm starts and 150 cold starts during its life.

(3) The sub-critical unit shall be designed for constant pressure and sliding pressure operation. The supercritical unit shall be designed for sliding pressure operation.

(4) The design shall cover adequate provision for quick start up and loading of the unit to full load at a fast rate. The unit shall have minimum rate of loading or unloading of 3% per minute above the control load (i.e. 50% MCR).

(5) The unit shall be capable of automatically coming down to house load and operation at this load in the event of sudden external load throw off.

(6) The unit shall be designed to give optimum efficiency for the stipulated fuel and other site specific conditions.

12. Steam Generator (Boiler) and Auxiliaries

(1) The steam generator shall normally be based on pulverized fuel combustion and shall be of sub-critical or super critical type with single pass or two pass or any other proven flue gas path configuration. However, wherever very low grade fuel or coal or lignite with high sulphur content is stipulated, fluidized bed combustion (FBC) based steam generator may also be considered based on Owner's assessment of techno - economics and availability of proposed unit size.

(2) Efficiency of the steam-generator (on high heat value basis) in %, as guaranteed by the manufacturer, shall not be less than the value as arrived with the following formula for the quality of performance coal or lignite:

$$\text{Minimum steam generator efficiency (\%)} = 92.5 - \frac{[\,50*A + 630(M+9*H)\,]}{HHV}$$

where ‘A’ is the percentage ash in fuel,
‘M’ is the percentage moisture in fuel
‘H’ is the percentage hydrogen in fuel and
‘HHV’ is high heat value of fuel

(3) The steam generator and its auxiliaries shall be suitable for outdoor installation.

(4) Boiler Maximum Continuous Rating (BMCR) shall correspond to at least 102% of the steam flow at turbine inlet under VWO condition plus continuous steam requirement for auxiliary systems of the unit (e.g. fuel oil heating, etc.) when unit is operating above control load. The steam generator shall be capable to give BMCR output for the worst fuel quality stipulated.

(5) All parts of the steam generator including pressure parts, vessels, piping, valves including safety valves and fittings shall meet the requirements of Indian Boiler Regulations (IBR).

(6) All start up vents shall be provided with two valves in series - one motorized isolating and other motorized regulating type.

(7) If indigenous coal is proposed as main fuel, its typical characteristics (high abrasive ash, slow burning, high ash resistivity, etc.) shall be given due consideration while designing the steam generator and auxiliaries.

(8) Pressure withstand capability of the furnace shall correspond to minimum +/- 660 mmwc at 67% yield strength or maximum expected pressure/draft of fans, whichever is higher.

(9) Maximum average gas velocity, when using indigenous coal, in any zone of furnace, superheater, reheater, economizer shall be 10 m/sec to prevent erosion of pressure parts. However, maximum local velocity can be upto 12 m/s.

(10) For pulverized coal or lignite based steam-generators, fuel oil firing system shall be provided for start up and low load flame stabilization. Light diesel oil (LDO) and/or heavy fuel oil shall be used for fuel oil firing system.

(11) Pulverised fuel combustion based steam generator shall not require oil support above 40% unit load. However, FBC based steam-generator shall be designed such that oil support is not needed beyond 25% load.

(12) (a) Design of pulverized fuel system shall comply with requirements of NFPA.

(b) Coal or lignite preparation system for pulverized fuel system shall have sufficient spare milling capacity (e.g. at least one spare mill when using worst coal corresponding to MCR in case of medium speed mills).

(c) Coal supply to the mills shall be from the individual coal bunkers having storage capacity of about 12 hours with the unit operation at MCR.

(d) The coal fineness achieved from the pulverisers shall be at least 70% thru 200 mesh (75 microns) and 98% thru 50 mesh (300 microns) at rated capacity of the pulveriser, with an input coal size up to 50 mm.

(13) 2x60% forced draft (FD) fans and 2x60% induced draft (ID) fans shall be provided to maintain balance draft conditions in the furnace over the entire load range while burning the stipulated range of fuel.

(14) Suitable air pre-heating system shall be provided for recovery of useful heat from the exhaust flue gases. Steam coil air pre-heater (SCAPH) may also be provided for maintaining air temperature within safe limits to prevent acid corrosion during start up or very low ambient air temperature conditions.

(15) The soot blowing system shall be provided for the waterwall, superheater, reheater, economizer and air preheater.

(16) The dust collecting system (electro-static precipitator, bag filter etc.) shall be provided for removing suspended particulate matter (SPM) from the flue gases to meet the statutory stipulation as per environmental clearance. Electro-static precipitator (ESP) shall comply with following requirements:

(a) ESP shall be able to meet the stipulated SPM emission requirement even when one electric field in each pass of the ESP is out of service while firing stipulated worst fuel with unit operation at MCR.

(b) ESP shall be provided with effective ash evacuation system having controls for ash temperature and ash level in the hopper. Each hopper shall have a storage capacity of minimum of eight (8) hours with unit operation at MCR.

(c) Specific weight of ash may be considered not more than 650 kg/m^3 for determining hopper storage capacity and not less than 1350 kg/m^3 for ESP structural design.

(d) Pressure withstand capability of the ESP casing shall correspond to minimum +/- 660 mmwc at 67% yield strength and flue gas temperature of 200^0C.

13. Steam Turbine and Auxiliaries

(1) The steam turbine shall comply with latest versions of relevant IEC or equivalent.

(2) The gross turbine cycle heat rate as guaranteed by the equipment manufacturer shall not exceed the following values:

Table: I- 1

Unit rating (MW)	Heat rate* (kcal / kWh) at 100% MCR with motor driven BFP	Heat rate* (kcal / kWh) at 100% MCR with turbine driven BFP
50 MW to less than 100 MW@	2280	
100 MW to less than 200 MW@	2000	-
200 MW to less than 250 MW@	1970	-
250 MW to less than 500 MW@	1955	-
500 MW and above@	1895	1935
Supercritical units	1810	1850

*corresponding to reference conditions of 33^{O} C cooling water temperature and 0% de-mineralised water make up

@ sub-critical units

(3) The steam turbine shall be of tandem or cross compound construction, reheat, condensing type with number of uncontrolled extractions as optimized for regenerative feed heating.

(4) The steam flow through steam turbine under valves wide open (VWO) condition shall correspond to 105% of steam flow corresponding to MCR output.

(5) A self-contained lubricating oil system shall be provided for each steam turbine-generator. A main oil pump (MOP) shall be provided which may be either directly driven by turbine shaft or by AC motor. In addition, a minimum of one AC motor driven auxiliary oil pump shall be provided as standby for the main oil pump. Provision shall also be made for one DC motor driven emergency oil pump for meeting lubricating oil requirement during non-availability of AC motor driven pump.

(6) Jacking oil system, with 2x100% jacking oil pumps (one AC driven and one DC driven), shall be provided to supply high pressure oil to bearings of steam turbine-generator to lift the rotor during starting or turning gear operation. Hand barring gear shall be provided for manually rotating the turbine in an emergency.

(7) The oil used for turbine governing (control) shall be either from the lubricating oil system or from a separate control oil system. In case of separate control oil system, the pumps provided shall be of 2x100% capacity.

(8) Each steam turbine shall be provided with one main oil tank of capacity 5 to 8 oil changes per hour (at normal operating level) and oil purification system of adequate capacity. In addition, the Station shall be provided with central turbine oil storage and purification system consisting of one pure oil tank, one dirty oil tank and oil purification unit.

(9) The steam turbine shall be provided with electronically controlled electro-hydraulic governing system. However, the steam turbines of rating higher than 200 MW shall be provided with back up governing system of mechanical hydraulic or electro- hydraulic type.

(10) The turbine shall be provided with protective devices as per relevant IEC or equivalent, including the following:

(a) Separately actuated over-speed trip device.

(b) Emergency hand trip devices to facilitate manual tripping of the turbine locally and from control room.

(11) Turbine vibrations shall be minimized and shall be within limits as per latest version of relevant ISO standards.

(12) Non-return valves shall be provided in the steam extraction lines as required for protection from overspeed that may result from sudden load throw off or turbine trip.

(13) Hydraulic/pneumatic/D.C. operated device shall be provided for rapid reduction of vacuum in condenser to bring turbine rotor to rest as quickly as possible under emergency conditions.

(14) The start up and drainage system shall comply with relevant ANSI/ASME Standard or equivalent regarding prevention of water damage to steam turbines.

(15) For steam turbines of rating higher than 100 MW, turbine by-pass system of capacity not less than 60% of BMCR steam flow shall be provided for fast hot & warm start ups of unit, dumping steam in condenser during sudden turbine trip (without tripping the steam generator), unit house load operation etc.

(16) Condensate polishing system shall be provided in the steam turbine cycle for the following:

(a) units with rated pressure of about 170 kg/cm^2 and above at turbine inlet;

(b) units with once- through steam generators;

(c) units using sea water for condenser cooling.

(17) Suitable feed water regenerative system consisting of low pressure heaters, deaerator and high pressure heaters shall be provided for optimized cycle efficiency. Feed water heaters and deaerator shall be designed in accordance with the ASME boiler & pressure vessels codes and HEI Standards or equivalent.

(18) Steam condenser shall meet the following requirements:

(a) The design, manufacturing and testing of condenser shall be as per HEI Standards or equivalent.

(b) Condenser tubes shall be of stainless steel except in case of units using sea water for cooling in which case condenser tubes shall be of titanium.

(c) On load condenser tube cleaning system shall be provided for regular cleaning of condenser tubes. Further, debris filter shall also be provided at condenser inlet for sea water application.

(d) Vacuum pumps or steam ejectors shall be provided as per HEI Standards or equivalent for evacuating air steam mixture and non-condensable gases from the condenser.

(19) 3x50% or 2x100% condensate extraction pumps shall be provided for each unit. The design shall meet the requirements of HIS or equivalent.

(20) The unit shall be provided with boiler feed pumps of adequate capacity to give rated output. The design shall meet the requirements of HIS or equivalent. The following configurations may be adopted subject to compliance of IBR:

(a) *Pulverised Fuel Combustion Based Steam generators*

2x50% or 1x100% turbine driven BFP(s) plus one (1) number motor driven BFP of adequate capacity for start up of the unit

or

2X50% motor driven BFPs

(b) *Fluidised Bed Combustion Based Steam generators*

2x100% motor driven BFPs

14. Electrical System

(1) General requirements

(a) For the purpose of design of electrical equipment and systems, an ambient temperature of 50^0C and relative humidity of 95% shall be considered. The equipment shall be suitable for operation in a highly polluted environment. However, for equipment installed in air conditioned areas, design ambient temperature shall be 35^0 C.

(b) The telecommunication system shall be based on optical fibre or PLCC or both. Owner's telecommunication equipment provided to transmit the required data of the Station to the procurer of electricity, Regional/ State Load Despatch Centre and Transmission Company shall have matching equipment and compatible communication protocol with the receiving end.

(2) Generator

(a) The generator shall comply with relevant IS/ IEC standard. The efficiency of generator shall be more than 98% at rated load.

(b) Insulation shall be thermal class- F for stator and rotor winding as per relevant IEC. However, temperature rise shall be limited corresponding to thermal class- B insulation. Generator shall be either hydrogen cooled or hydrogen & water cooled or air cooled type**.** The hydrogen cooled generator shall be capable of delivering at least two third of its rated output with one hydrogen gas cooler out of service.

(c) Resistance temperature detectors (RTDs) or thermocouples shall be provided at suitable locations for monitoring the temperatures of stator core, stator windings and bearings. Suitable arrangements shall also be made for monitoring the temperature of the rotor winding in case static excitation system is provided.

(d) For hydrogen cooled generators, hydrogen gas system shall be provided with driers of 2x100% duty to maintain dryness of hydrogen inside the machine. Suitable system shall be provided to prevent condensation during long shut down. The system shall have the provision of on-line dew point measurement as well as gas analyser.

(e) For water cooled stator winding, stator water cooling system shall be closed loop type with 2x100% AC motor driven circulating water pumps, 2x100% de-mineralised (DM) water heat exchangers, 2x100% filters, one mixed bed de-mineraliser and one alkalizer unit (as applicable).

(f) In case of hydrogen cooled machines, the seal oil system provided shall be equipped with 2x100% AC motor driven pumps and 1x 100% DC motor driven pump. The system shall be provided with coolers and filters having 2x100% duty.

(g) *Excitation System*

(i) Suitable generator excitation system as well as automatic voltage regulator (AVR) shall be provided with the generator as per Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007. Power system stabilizer (PSS) shall be provided in AVR for generator of 100MW and higher rating.

(ii) The rated current of the excitation system shall be at least 110% of the machine excitation current at the rated output of the machine. The rated voltage shall be at least 110% of the machine excitation voltage.

(iii) Automatic voltage regulator shall have 2x100% auto channels and automatic changeover. In the event of failure of auto channels, manual control shall be possible. At least 100% redundancy shall be provided for the converters including power supply. In case of brushless excitation system, rectifier assembly shall be provided with either complete bridge as redundant or at least one redundant parallel branch in each of the six arms of the bridge.

(h) *Instrument Transformers*

(i) *Current transformers*

The type and accuracy of current transformers for protection purposes shall comply with relevant IS/ IEC Standards. Current transformers for metering shall also comply with Central Electricity Authority (Installation and Operation of Meters) Regulations, 2006.

(ii) *Voltage transformers*

The type and accuracy of Voltage transformers for protection purposes shall comply with relevant IS/ IEC Standards. Voltage transformers for metering shall also comply with Central Electricity Authority (Installation and Operation of Meters) Regulations, 2006.

(3) **Power transformers**

(a) The power transformers (generator transformer, unit auxiliary transformers, station transformers) shall comply with latest versions of relevant IS/IEC Standards.

(b) The generator transformer shall be provided to step up generating voltage for connection to the grid. It shall also be used to provide start-up power from the grid in case circuit breaker is provided between the generator and generator-transformer in generator circuit breaker (GCB) scheme.

The generator transformer shall be mineral oil filled with oil forced air forced (OFAF) cooling. Alternate cooling arrangement viz. oil natural air forced (ONAF), or oil natural air natural (ONAN) may also be adopted depending upon unit size. It shall be provided with two or more cooling radiator banks. Suitable number of standby fans and oil pumps shall be provided.

The generator transformer shall be provided with on-load tap changer (OLTC) or off-circuit tap changer (OCTC) depending upon system requirements.

(c) The unit auxiliary transformer(s) (UAT) shall be used to meet the unit load requirement during normal running of the unit. However, in case of GCB scheme, it shall provide power requirement of the unit auxiliaries and station auxiliaries during start-up and normal running of the unit.

The unit auxiliary transformer shall be mineral oil filled with oil natural air forced (ONAF) or oil natural air natural (ONAN) cooling. However, oil forced air forced (OFAF) cooling may also be adopted depending upon transformer size. It shall be provided with two or more cooling radiator banks. Suitable number of standby fans and oil pumps shall be provided.

The tap changer for UAT shall be of OCTC type in case generator transformer is provided with OLTC and vice versa.

(d) The station transformer(s) shall cater to start-up power requirement, station auxiliary load requirement during normal operation of the unit(s) and outage of UAT. In case of GCB scheme, station transformer may not be required.

The station transformer shall be mineral oil filled with oil forced air forced (OFAF) cooling. Alternate cooling arrangement viz. oil natural air forced (ONAF), or oil natural air natural (ONAN) may also be adopted depending upon unit size. It shall be provided with two or more cooling radiator banks. Suitable number of standby fans and oil pumps shall be provided.

The tap changer shall be of OLTC type.

(e) The transformers shall be suitable for continuous operation at rated MVA on any taps with voltage variation to meet the system requirement.

(f) The insulation levels for the transformer windings and bushings shall be as per Table III- 5 under clause 47.

(g) Short circuit withstand test shall be conducted on one of each type and rating of power transformers to validate the design and quality unless such test has been conducted within last five years on transformer of same design. In case there is a change in design before five years, the new transformer design shall be validated by carrying out short circuit withstand test.

(h) Mobile centrifuging plant of adequate capacity shall be provided for purifying the transformer oil. The centrifuge plant shall be complete with on-line testing instruments and annunciating panel.

(4) **HT switchgear**

SF6 or vacuum type of circuit breakers shall be provided for HT switchgear (11/6.6/3.3 kV) which shall be of draw out type, re-strike free, trip free, stored energy operated and with electrical anti-pumping features. The protective relays shall be preferably of numerical type with self monitoring and diagnostic features. The switchgear shall be designed for suitable fault withstanding capability.

(5) **LT switchgear**

Air break type of circuit breakers shall be provided for LT switchgear (415 V) which shall be of draw out type, trip free, stored energy operated and with electrical anti-pumping features. The protective relays shall be preferably of numerical type with self monitoring and diagnostic features. The switchgear shall be designed for suitable fault withstanding capability.

(6) **Busducts**

(a) The busducts shall be of standard size as per relevant IS and designed to carry maximum continuous current under normal site conditions without exceeding temperature rise limits.

(b) The generator busducts shall be segregated or isolated phase type. The busduct rated more than 3150 Amp and upto 6000 Amp shall be isolated phase type. The busduct rated more than 6000 Amp shall be continuous isolated phase type. A hot air blowing system or air pressurization system shall be provided to prevent moisture deposition in case of isolated phase busducts while space heaters may be provided in case of other busducts.

(c) Surge arresters and voltage transformers connected to generator busducts shall be located in separate cubicles for each of the three phases. Voltage transformers shall be accommodated in draw-out type compartments in phase-isolated manner in a cubicle. The surge arresters and voltage transformers cubicles shall comply with relevant IS / IEC Standards.

(d) The HT busduct (11/6.6/3.3 kV) shall be segregated phase type and LT busduct (415V) shall be non-segregated phase type.

(e) The bus assembly shall be designed mechanically to withstand rated continuous current as well as the specified short-circuit current without damage or permanent deformation of any part of the bus structure.

(7) **Power supply system**

(a) All auxiliaries dedicated to the unit shall be fed from the unit bus connected to UAT(s). During start -up and shut - down of the unit, the unit auxiliaries shall be supplied power from the station bus connected to station transformer(s). However, in case of GCB scheme, the same shall be provided by the unit bus.

(b) All the loads pertaining to balance of plant facilities shall be fed from station bus connected to Station transformer(s). Station bus shall also be capable of supplying power to largest unit in the Station during start-up and shut-down. However, in case of GCB scheme, the loads pertaining to balance of plant facilities shall be fed from the unit bus.

(c) Power supplies, buses, switchgears, interlocks and standby supply systems for station and unit auxiliaries shall be designed in such a way that the main equipment and auxiliaries are not endangered under all operating conditions. Transformer voltage ratios, type of tap changers and tap ranges, impedances and tolerances thereon shall be so optimized that the auxiliary system voltages under various grid and loading conditions are always within permissible limits and equipment are not subjected to unacceptable voltages during operation and starting of motors. The vector groups of the generator transformers, unit auxiliary transformers and station transformers shall be so selected that the paralleling at 11/ 6.6/ 3.3kV buses shall be possible. Further, the vector group of other auxiliary transformers shall have identical vector groups.

(d) In thermal power stations with unit sizes greater than 100 MW, automatic bus transfer system (consisting of fast, slow, etc. transfer in auto mode) shall be provided to minimise time for transfer from unit to station buses at 11/ 6.6 kV levels. Bus transfer scheme shall also have manual mode to initiate transfer including live changeover through synchronisation.

The 11/6.6/3.3 kV switchgear buses for balance of plant facilities shall be provided with auto reserve closure (ARC) facility between main incomer and reserve breakers. Critical 415 V switchgear buses shall also have ARC feature.

(e) Auxiliary transformers, as required, shall be provided to meet the demand at various voltage levels of auxiliary power systems, with the criteria that each switchgear, motor control centre (MCC), distribution board (DB) shall be fed by 2x100% transformers/ feeders. The auxiliary transformers shall be designed to carry the maximum expected load.

(8) **Neutral earthing**

The earthing of neutral of various systems shall be as follows:

Generator star point	:	Through dry type distribution transformer with secondary loaded with a resistor.
Generator transformer, Station transformer - HV winding star point	:	Solidly earthed
11 kV, 6.6kV or 3.3 kV system	:	Through a resistance in case of star connected windings Or Through artificial transformer with its secondary loaded with resistor in case of delta connected windings

415 V system : Solidly earthed

DC system : Unearthed

(9) **Earthing system**

The earthing system shall be designed for a life expectancy of at least forty (40) years and for maximum system fault current or 40kA for 1.0 sec, whichever is higher. The minimum rate of corrosion of steel used for earthing conductor shall be considered as 0.12 mm per year while determining the conductor size.

Grounding and lightning protection for the entire Station shall be provided in accordance with relevant IS/ IEEE Standards.

(10) **Protection system**

Fully graded protection system with requisite speed, sensitivity and selectivity shall be provided for the entire station. The electrical protection functions shall be provided in accordance with but not limited to the list given below:

(a) Generator, generator transformer, unit auxiliary transformer(s) shall be provided with protection systems connected to two independent channels/ groups, such that one protection system shall always be available for any type of fault in the generator/ generator transformer/ UAT(s).

(i) *Generator*

Table: I- 2

Sl. N0.	Protection Function	Remarks
1	Generator differential protection (87G)	
2	100% stator earth fault protection (64G)	For units of 100 MW and above
3	95% stator earth fault protection (64G1)	For units less than 100 MW
4	Standby stator earth fault protection (64G2)	
5	Inter-turn fault protection (87TG)	Applicable where split winding in Stator is provided and if six terminals are available.

6	Loss of field protection (40G)	To be duplicated for units of 500 MW and above.
7	Negative phase sequence current protection (46G)	
8	Low-forward power and Reverse power interlock for steam turbine generator (37/ 32G)	Preferably 3-phase power relays shall be provided. Both the relays shall be duplicated for units of 500 MW and above.
9	Rotor earth fault protection - two stages (64F1/F2)	
10	Definite time over-voltage protection (59G)	
11	Generator under frequency protection (81G)	
12	Over-fluxing protection for generator (99G)	To be provided for units of 500 MW and above in duplicate.
13	Overload protection for generator (51G)	
14	Overheating (winding and/ or bearing) (49G)	Alarm only
15	Instantaneous and time delayed over current protection on high voltage side of excitation transformer (51)	
16	Generator pole slipping protection (98G)	
17	Accidental back energisation protection (50GDM)	
18	Generator circuit breaker failure protection (50ZGCB)	To be provided for GCB scheme only

In case digital multifunctional generator protection system (MGPS) is provided, the protection systems for generator shall be duplicated for units of 100MW and above. Each MGPS shall preferably be provided with individual inputs from CTs and VTs and connected to the independent set of hand-reset trip relays, such that one set is always available in case of testing and mal-operation of the other set. If the MGPS does not include any protection mentioned in the table above, separate discrete protection shall be provided for the same. The MGPS shall preferably have continuous self-monitoring and testing facilities.

(ii) *Generator transformer*

Table: I- 3

Sl. N.	Protection Function	Remarks
1	Overall differential protection (87OA)	
2	Generator transformer differential protection (87GT) for single phase bank	
3	Restricted earth fault protection for generator transformer (87NGT)	
4	Over head line connection differential protection (87L)	For 3 single phase banks, if 87L includes HV winding, separate 87NGT is not mandatory.
5	Back- up impedance protection, 3 pole (21G)	
6	Back- up earth fault protection on generator transformer HV neutral (51NGT)	
7	Over-fluxing protection for generator transformer (99GT)	To be duplicated for units of 500 MW and above.
8	Back- up non-directional over-current protection in all phases on HV side of generator transformer (51GT)	
9	Generator transformer OTI (49Q) and WTI (49T) trip	
10	Generator transformer Buchholz (63), PRV / other mechanical protections	
11	Pole discrepancy protection of generator transformer breaker (162)	To be provided, if single pole breakers are used.
12	Breaker failure protection of generator transformer breaker (50Z)	
13	Start-up earth fault protection for LV and HV winding of generator transformer and UATs (64T)	To be provided for GCB scheme only.

(iii) *Unit auxiliary transformer(s)*

Table: I- 4

Sl. N.	Protection Function
1	Differential protection (87UAT)
2	LV back-up earth fault protection (51NUAT)
3	LV restricted earth fault (87NUAT)
4	Back-up over-current protection (51UAT)
5	OTI(49Q) and WTI (49T) trip
6	Buchholz (63), PRV/ other mechanical protections

(b) *Station Transformer(s)*

Table: I- 5

Sl. N.	Protection Function
1	Differential current protection (87)
2	Restricted earth fault protection for LV winding (87NLV)
3	Restricted earth fault protection for HV winding (87NHV)
4	Back-up over-current protection on HV side (51)
5	Back-up earth-fault protection (51N)
6	Over-fluxing protection (99)
7	Buchholz protection (63)
8	Winding temperature high (49T)
9	Oil temperature high (49Q)
10	Pressure relief valve trip (PRV)
11	Breaker failure protection (50Z)

(11) **Synchronization**

Automatic as well as manual facility alongwith check synchronizing and guard relay features shall be provided for closing of generator transformer/ generator circuit breaker for synchronization of generator with the grid. HT auxiliary buses shall also be provided with manual synchronizing facility.

(12) **Power and control *c*ables, and cabling**

(a) Power and control cables shall be flame retardant low smoke (FRLS) type. However, fire survival (FS) cables shall be provided for certain essential auxiliaries/ areas. Cables to be directly buried shall be essentially armoured type. FRLS cables and FS cables shall meet test requirements as per relevant ASTM, IEC, IEEE and SS (Swedish Standards).

Derating factors for site ambient and ground temperatures, grouping and soil resistivity shall be considered while determining the size of cables.

(b) Cable installation shall be carried out as per relevant IS and other applicable standards. Power cables and control cables shall be laid on separate tiers. The laying of different voltage grade cables shall be on different tiers according to the voltage grade of the cables with higher voltage grade cables in topmost tier and control cables in bottommost tier. All cables associated with one unit shall preferably be segregated from cables of other units. Cable routes for one set of auxiliaries of same unit shall be segregated from the other set.

(13) **Diesel generator set**

Automatic mains failure (AMF) diesel generators (DG) shall be installed for feeding emergency loads in the event of failure of Station supply. One DG set shall be provided for each unit of 200 MW and above. In addition, there shall be one common standby DG set of same rating to serve a block of two units. For unit sizes less than 200 MW, one DG set may be provided for every two units. However, a Station with a single unit of 200 MW or higher rating shall be provided with two DG sets.

(14) **DC system**

Standard voltage levels of the DC system shall be 220 volts, 48 volts and 24 volts for control and protection of various equipment. Two sets of batteries, each catering to 100% load, shall be provided for each DC system. One float -cum- boost charger shall be provided for each battery.

(15) **Illumination system**

Adequate illumination shall be provided in accordance with relevant IS. Emergency AC and DC illumination shall also be provided at important places. Energy conservation measures shall be adopted while designing the lighting system.

(16) **Motors**

AC motors shall be squirrel cage induction type suitable for direct on-line starting and shall comply with relevant IS. However, the crane duty motors may be slip ring/ squirrel cage induction type. DC motors shall be shunt wound type.

All motors shall be either totally enclosed fan cooled (TEFC) or totally enclosed tube ventilated (TETV) or closed air circuit air cooled (CACA) or closed air water cooled (CACW) type. Temperature rise shall be limited to 70^{0} C by resistance method for both Class- B and Class- F insulation.

The degree of protection of all the motors shall be IP- 55. However, outdoor motors shall be provided with suitable canopies. Enclosures of the motors located in hazardous areas shall be flame proof type conforming to relevant IS.

15. Control and Instrumentation System

(1) **General**

(a) Control and Instrumentation system provided for the Station shall be consistent with modern power station practices and in compliance with all applicable codes, standards, guidelines and safety requirements in force.

(b) The complete thermal, mechanical and electrical functions of the unit shall be remotely controlled from the central control room and those of balance of plant facilities shall be controlled from respective local control room during normal as well as emergency conditions. The number of control areas shall be kept to the minimum with a view to optimizing manpower requirement.

(c) All stand-by auxiliaries shall be designed to start automatically as quickly as possible on failure of running auxiliaries as per process requirement.

(2) **Control system for steam generator and turbine generator**

(a) The state of art microprocessor based distributed digital control, monitoring and information system (DDCMIS) shall be provided for monitoring and control of steam generator, turbine generator and auxiliaries and shall include monitoring & information, sequential control for drives, closed loop control for regulating drives, interlocking & protection, historical data storage, alarm annunciation system, sequence of events (SOE) recording system etc. The DDCMIS shall be independent for each unit.

(b) Control systems integral to steam generator and turbine- generator shall be implemented as part of DDCMIS. However, Turbine Protection System and Electro-Hydraulic Governing System may be implemented as per standard practice of turbine manufacturer.

Control systems integral to steam generator shall include furnace safeguard supervisory system (FSSS) (comprising burner management system, master fuel trip, mills automation etc.) which shall comply with latest version of NFPA code. The master fuel trip (MFT) system shall comply with requirements of relevant NFPA/VDE codes.

Control systems integral to turbine- generator shall include turbine protection system, electro-hydraulic governing (EHG) system, turbine stress control system, turbine supervisory system, automatic turbine run up system (ATRS) and automatic on load turbine testing system (ATT). Turbine protection system shall comply with relevant VDE code.

(c) Human machine interface system (HMIS) configured around latest state-of- art redundant workstations with open architecture shall be provided to operate the unit under all operating conditions. Minimum number of hardwired devices shall also be provided for safe shutdown of unit as a back- up. In addition, large video screens (LVS) may also be provided in the control room.

(d) DDCMIS shall be provided with 100% redundancy for processors, control & input/output bus as well as network components.

(e) All input modules for control, interlocking and protection shall be provided with redundancy. Output modules for all HT drives and critical LT drives shall also be provided with redundancy. Redundant inputs/outputs shall be connected to different input/output cards of DDCMIS i.e. triple redundant inputs shall be connected to three separate input cards. The logics for redundant drives shall not be in the same processor.

(f) The design of the control systems and related equipments shall adhere to the principle of ‘fail safe operation’ wherever the safety of personnel and plant equipment is involved. ‘Fail safe operation’ signifies that the loss of signal, loss of power or failure of any component shall not cause a hazardous condition. However, it shall also be ensured that occurrence of false trips is minimized. No single failure either of component or power source of DDCMIS shall cause loss of generation.

(g) The control system shall include on-line self-surveillance, monitoring and diagnostic facility providing the details of each fault at the human machine interface system (HMIS).

(h) It shall be possible to remove and replace various modules (like any input/output module, interface module, etc.) on-line from its slot for maintenance purpose without switching off power supply to the corresponding rack and without jeopardizing safety of the Station equipment and personnel.

(i) The historical data storage and retrieval system shall store and process system data for future analysis. The data shall be transferable to removable storage media for long term storage and retrieval. The binary data to be stored shall include status of SOE (1milli-second resolution), alarm and other binary inputs. All important analog data shall be stored at one second interval. Selected logs viz. start up log, trip analysis log shall also be stored.

(j) Master and slave clock system shall be provided to ensure uniform timing in all the control systems across the entire plant.

(k) All coal or lignite fired units of size 250 MW and above shall be provided with on-line efficiency monitoring and optimization system to maximize the operational efficiency.

(3) **Control system for balance of plant**

Programmable logic controller (PLC) based or DDCMIS based control system with independent HMIS shall be provided for all the balance of plant facilities like coal or lignite handling plant, ash handling plant, water treatment plant etc. PLCs shall be latest state of the art system with redundant processors. For minor balance of plant systems, the control systems may be relay based.

(4) **Local area network (LAN)**

A redundant industrial grade station-wide LAN shall be provided for information exchange between DDCMIS of each generating unit, PLCs for balance of plant as well as gateway for connecting to the other off-line services of the Station (computerized inventory management, maintenance management systems etc.).

(5) **Communication system**

An effective communication system shall be provided to facilitate quick communication among the operating personnel at various locations of the power station.

(6) **Measuring instruments and systems**

(a) Primary instruments like transmitters, thermocouples, resistance temperature detectors (RTDs), local gauges, flow elements, transducers etc. shall be provided as required for comprehensive monitoring of various parameters of the Station locally as well as in control room(s) through DDCMIS.

(b) Microprocessor based vibration monitoring and analysis system shall be provided for monitoring and analysis of vibration of critical rotating equipment (i.e. turbine- generator, boiler feed pumps, ID/FD/PA fans etc.)

(c) On line flue gas analysis instruments including sulphur-di-oxide (SO_2), nitrogen oxides (NOx), oxygen, carbon mono-oxide (CO) and dust emission monitoring systems shall be provided.

(d) The triple sensors shall be provided for critical binary and analog inputs required for protection of steam generator and steam turbine as well as for critical control loops (e.g. furnace draft, drum level, condenser vacuum). Redundant sensors shall be provided for other important applications.

(e) All electrical instruments and devices like switches, transmitters, controllers, analyzers, solenoid valves which are located in the hazardous locations like hydrogen generation plant shall be provided with explosion proof enclosure suitable for hazardous areas as per NFPA/ NEC.

(7) **Power supply system**

Independent, redundant and reliable 230 V or 110 V AC through uninterrupted power supply system (UPS) and/or DC power supply at standard voltage levels (e.g. 220V/ 48V/ 24V) shall be used for control & instrumentation systems.

(8) **Control valves**

The control valves and accessories shall be designed, constructed and tested as per IBR, ASME code for power cycle piping and ASME Boiler & pressure vessel code or equivalent.

(9) **Steam and water analysis system (SWAS)**

An on-line sampling and analysis system shall be provided, as per the recommendation of manufacturers of steam-generator and steam turbine, for continuously monitoring the quality of condensate, feed water, steam etc.

16. Balance of Plant

(1) Coal or lignite handling system

The arrangement for transportation of coal or lignite from supply source to the Station may be by rail or other captive systems such as merry go round (MGR), belt conveyor system, ropeway system etc. Further handling shall comply with the following requirements:

(a) The coal or lignite handling plant capacity shall be such as to meet the day's fuel requirement by its operation in 14 hours. A day's fuel requirement shall be worked out at 100% BMCR using worst coal or lignite plus a margin of 10%.

(b) The coal or lignite handling plant shall be provided with 100% standby streams. Each coal or lignite stream shall be provided with 2x75% or 3x50% paddle feeders (in case of track hoppers) or vibro feeders (in case of wagon tippler) and 2x50% crushers with belt feeders. Single set of coal or lignite conveyers from the stockyard to the bunkers shall not cater to more than three units.

(c) In case of rail based transportation, marshalling yard for handling of wagons and unloading system shall be designed to facilitate return of empty wagons within the time prescribed by the Indian Railways under the worst seasonal conditions.

(d) Provision of proper dust suppression facility shall be made for coal at various locations i.e. receiving point, stockyard and discharge points of conveyors to avoid dust nuisance and spontaneous fire.

(e) The provision for measurement of weight of coal or lignite shall be made through weighbridges at the receiving point. The weight of coal or lignite fed to individual units shall also be measured through belt-weighers.

(f) Magnetic separator system for removal of ferrous materials and detectors for non-ferrous materials shall be provided on the conveyor system.

(g) Arrangement shall be made for sampling of coal or lignite, and associated instruments/ equipment shall be provided to monitor quality of coal or lignite on as- received basis as well as on as- fired basis before the bunkers.

(2) **Fuel oil system**

(a) Necessary arrangement shall be made for unloading and storage of fuel oil(s).

(b) The capacity of fuel oil storage facilities shall be adequate for the requirement of fuel oil for at least 30 days' operation of the Station.

(c) Suitable heating arrangement shall be made for heating the heavy fuel oil by steam to maintain its flowability.

(d) The aspects regarding proper storage and handling of fuel oil shall be as per statutory requirements of Chief Controller of Explosives.

(e) Suitable measuring and recording facilities shall be provided for quantum of fuel oil(s) received and used.

(3) **Ash handling system**

(a) (i) Ash management plan for utilization and disposal of fly ash as well as bottom ash shall be formulated in accordance with MOE&F's requirements and any other stipulation of the CPCB and SPCB in this regard.

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(ii) Ash pond management shall be judiciously planned to optimize the land use and facilitate utilisation of pond ash. It shall also conform to MOE&F requirements and any other stipulation of the CPCB and SPCB in this regard.

(b) *For Pulverised Fuel Based Steam Generator*

(i) Arrangement shall be provided for extraction of 100% of fly ash produced and its transportation to silos in dry form.

(ii) Dry fly ash storage silos of adequate capacity (about 16 hours of ash generation with unit operation at MCR) to collect dry fly ash shall be provided in a separate area near the Station boundary with provision for independent access.

(iii) In addition to fly ash disposal in dry form, the provision may also be made for disposal through wet slurry system or high concentration slurry system. In case of wet slurry system, suitable ash water recirculation system shall be provided to recycle and reuse water.

(iv) Furnace bottom ash alongwith economizer ash shall be extracted and disposed in wet, semi-wet or dry form.

(v) The capacity of ash handling systems, as a percentage of maximum ash generated corresponding to firing of worst coal or lignite at BMCR, shall not be less than the following:

- Fly ash system
  - ESP fly ash and chimney ash : 90%
  - Air preheater ash : 5%

- Bottom ash system
  - Furnace bottom ash : 25%
  - Economiser ash : 5%

(vi) Ash removal rate shall meet the following criteria:

- Fly ash system : 8 hour collection in 6 hours

- Bottom ash system : 8 hour collection in 90 minutes for wet/semi-wet system and continuous for dry system

(vii) Ash handling system shall have the provision for following standby arrangement:

- Bottom ash system - 100% standby for jet pumps with 2x100% pipelines for each jet pump outlet for wet/semi-wet system
  or
  100 % standby for submerged scrapper conveyor (SSC) for wet system

- Fly ash system
  - 100% standby for vacuum pumps, collector tanks, wetting heads
  - 100% standby blowers for intermediate and storage silos
  - 100% standby for air compressors to be used for transporting ash

- Ash slurry disposal
  - One pump stream as operating standby and one pump stream as maintenance standby for wet slurry system
  - One standby stream for high concentration slurry system

(c) *For Fluidized Bed Steam Generator*

(i) Dry fly ash extraction, transportation and storage system shall meet the requirements as stipulated above for pulverized fuel based system.

(ii) In addition to fly ash disposal in dry form, the provision may also be made for disposal through wet slurry system or high concentration slurry system. In case of wet slurry system, suitable ash water recirculation system shall be provided to recycle and reuse water.

(iii) Furnace bottom ash shall be extracted in dry form by means of drag link chain conveyor and further disposed in wet, semi-wet or dry form.

(iv) The capacity of ash handling systems, as a percentage of maximum ash generated corresponding to firing of worst fuel at BMCR, shall not be less than the following:

- Fly ash system
  - ESP fly ash & chimney ash : 80%
  - Air preheater ash : 5%

- Bottom ash system
  - Furnace bottom ash : 30-40%
  - Economiser ash : 5%

(v) Ash removal rate shall meet the following criteria:

- Fly ash system : 8 hour collection in 6 hours

- Bottom ash system : Continuous

(vi) Ash handling system shall have the provision for following standby arrangement:

- Bottom ash system - 100% standby for drag link chain conveyor

- Fly ash system
  - 100% standby for vacuum pumps, collector tanks, wetting heads
  - 100% standby blowers for intermediate and storage silos
  - 100% standby for air compressors to be used for transporting ash

- Ash slurry disposal
  - One pump stream as operating standby and one pump stream as maintenance standby for wet slurry system
  - One standby stream for high concentration slurry system

(4) **Station water system**

(a) *Station Water Scheme*

(i) The station water scheme shall be designed to meet the total clarified water requirement of the Station consisting of cooling tower make up (for non-coastal stations), de-mineralised water, service water, potable water and miscellaneous requirements.

(ii) For coastal Stations, sea water shall be used for cooling of condenser and secondary cooling of plate heat exchangers, and clarified (non-saline) water shall be used for de-mineralisation system, service water, potable water and miscellaneous requirements. In case non-saline water is not available, sea water shall be used for production of non-saline water through desalination plant.

(iii) Raw water for production of clarified water shall be drawn from identified source of water and supplied to the Station site by raw water pumps with adequate standby provision and 2x50% or 1x100% capacity pipelines. Provision for de-silting (if required) and traveling water screens shall be made at the raw water intake point. Adequate storage of raw water shall be provided at the Station site considering the period of non-availability of input water from the source.

(iv) In case of sea water, de-silting arrangement and traveling water screens shall be provided at the sea water intake.

(b) *Pre-treatment System*

The raw water shall be treated in pre-treatment plant to produce clarified water for meeting the requirement of clarified water of the Station. Adequate provisions for raw water chlorination, chemical dosing and sludge handling shall also be made.

(c) *Cooling Water System*

(i) The cooling water (CW) system for condenser and secondary cooling system for Station equipment shall be clarified water based and shall be of closed cycle type using cooling towers. However, for coastal Stations using sea water, once through cooling system may be used which shall conform to MOE&F's requirements of temperature rise and any other stipulation of the CPCB and SPCB in this regard.

(ii) The cooling tower shall be of mechanical induced draft type or natural draft type depending upon site specific techno-economics. The design wet bulb temperature of the cooling tower shall correspond to the ambient wet bulb temperature which is not exceeded for more than 5% duration over one year period. Adequate recirculation allowance shall be considered for arriving at design wet bulb temperature for induced draft cooling tower.

The relative humidity, to be adopted for design of natural draft cooling tower, shall be appropriately selected considering annual variation of relative humidity in combination with wet bulb temperature.

(iii) The design of CW pump house shall be based on sump model studies and hydraulic transient analysis shall be carried out for CW piping system.

(iv) CW pumps shall be provided on unit basis for supply of cooling water. The standby pump(s) may be on unit basis or common to the Station. The CW pumps shall normally be of vertical wet pit type. However, concrete volute pumps may also be used particularly for sea water applications.

(v) Chemicals such as chlorine, acid, anti-scalant, biocide shall be dosed in the CW system for improving quality of circulating water and reducing its scaling and corrosive tendency.

(d) *De-mineralisation System*

(i) The capacity of de-mineralised (DM) plant shall be based on the requirement of de-mineralised water for heat cycle make-up, equipment cooling system make-up, regeneration of DM plant and condensate polishing plant, if envisaged. The DM plant shall be designed to produce the daily requirement of de-mineralised water of the Station in twenty (20) hours of operation of the DM plant. Adequate redundancy shall be provided in the number of de-mineralising streams.

(ii) The demineralized water shall be stored in minimum 2 nos. DM water storage tanks of total storage capacity equal to 24 hour Station requirement.

(e) *Waste Water Treatment System*

The waste water generated at various locations shall be segregated at the source of generation according to its type. Similar type of waste water shall be collected at one point and treated. The treated water shall be collected in central monitoring basin and recycled for plant use or disposed off complying with the requirements of MOE&F and any other stipulation of the CPCB and SPCB in this regard.

(5) **Fire detection, alarm and protection system**

(a) A comprehensive fire detection, alarm as well as fire protection system shall be installed for the Station in conformity with relevant IS. In addition, all buildings shall conform to National Building Code. Fire protection system shall be designed as per the guidelines of Tariff Advisory Committee (TAC) established under Insurance Act 1938 and /or NFPA.

(b) Automatic fire detection and alarm system shall be intelligent and addressable type and shall be provided to facilitate detection of fire at the incipient stage and give warning to the fire fighting staff.

(c) Major equipment to be used for fire detection and protection system shall be in accordance with Indian Standards or UL (Underwriters Laboratories, USA) or FM (Factory Mutuals, USA)

(d) Dedicated fire water storage and pumping facilities shall be provided for the fire fighting system as per TAC guidelines. Main fire water pumps shall be electrically driven and standby pumps shall be diesel engine driven.

(e) Hydrant system, complying with TAC guidelines, shall be provided at various locations to cover the entire Station.

(f) All major and minor fire risks in the Station shall be protected against fire by suitable automatic fire protection systems. Following systems shall be generally adopted for various fire risks:

(i) Automatic high velocity water spray system, complying with TAC guidelines, shall be provided for the following areas :

- Transformers of rating 10 MVA and above or oil filled transformers with oil capacity of more than 2000 litres.

  Alternatively, these transformers may be provided with Nitrogen injection based fire protection system. The transformers of 220kV or higher voltage may preferably be provided with Nitrogen injection based fire protection system in addition to automatic high velocity water spray system.

- Lube oil systems including storage tanks, purifier units, coolers, turbine oil canal pipelines

- Generator seal oil system tanks, coolers

- Steam generator burner fronts

(ii) Steam turbine bearing housing and air pre-heater shall be provided with manually actuated high velocity water spray system.

(iii) Automatic medium velocity water spray system, complying with TAC guidelines, shall be provided for the following areas:

- Cable galleries, cable vaults, cable spreader rooms, cable risers, cable shafts etc.
- Coal conveyors, transfer points, crusher houses, etc.
- Fuel oil pumping stations
- DG set building

(iv) Automatic foam system shall be provided for fuel oil storage tanks as per NFPA.

(v) Automatic inert gas flooding system, comprising of 2x100% inert gas cylinder batteries and conforming to NFPA, shall be provided for Unit control rooms, control equipment rooms and area above false ceiling of these rooms.

(g) Portable fire extinguishers as per TAC guidelines shall be provided for each room/area of power station in addition to fixed fire protection system to extinguish fire in its early phase to prevent its spread.

(h) Fire station and fire tenders alongwith trained staff shall also be provided for the Station.

(i) Passive fire protection measures such as fire barriers for cable galleries and shafts etc., fire retardant coatings, fire resistant penetration sealing for all openings in floors, ceilings, walls etc., fire proof doors etc. shall be provided to prevent spreading and for containment of fire.

(6) **Compressed air system**

(a) Compressed air system comprising of instrument air and service air shall be provided to cater to the requirement for operation of various pneumatically operated drives and general purpose cleaning & maintenance services. Air dryers shall be provided for instrument air to achieve desired dryness.

(b) At least one number service air and one number instrument air compressor shall be provided as standby.

(7) **Ventilation and air-conditioning system**

(a) Suitable ventilation and air-conditioning system shall be provided to achieve proper working environment in the Station.

(b) Normally central control room, local control rooms and service building for O&M personnel shall be air conditioned. Air- conditioned areas shall be maintained at about 25°C and 50 % relative humidity for comfort conditions.

Water chilling unit or condensing units shall have 2x100% capacity equipment. Package type air-conditioners shall have 2x100% capacity or 3x50% capacity equipment. For window air conditioners and split air conditioners, if used for small control rooms, at least one unit shall be kept as standby.

(c) The type of ventilation systems to be provided for non-air conditioned areas shall be as under:

- All floors of TG building, switchgear rooms and cable gallery	: Evaporating cooling system
- Other buildings	: Mechanical ventilation system

(8) **Mill rejects system**

The mill rejects system shall be provided to collect reject from coal mills in case of vertical mills. The system shall be mechanized i.e. drag chain conveyor or pneumatically pressurized conveying system. The system shall consist of collection of rejects from each coal mill and transport to silos for final disposal.

(9) **Electric overhead travelling (EOT) crane**

(a) The EOT cranes shall be provided for maintenance of TG cycle equipment and CW pumps. These shall comply with the requirements of latest versions of relevant IS. The crane capacity shall be taken as 10% more than the single heaviest equipment to be lifted.

(b) Two EOT cranes may be provided for maintenance of TG cycle equipment in case more than two steam turbine generators are housed in the TG hall.

(10) **Laboratories**

Station shall be provided with following laboratories:

(a) Electrical laboratory with necessary equipment and instruments for testing and maintenance of electrical equipment.

(b) Control & Instrumentation laboratory with necessary equipment and instruments for testing, calibration and maintenance of control & instrumentation systems.

(c) Chemical laboratories with necessary equipment, instruments and reagents for chemical analysis in water treatment plant, steam & water analysis and analysis of coal, ash & flue gas.

17. Civil Works

Civil aspects are site specific and depend upon topographical, geo-technical and other studies. The design philosophy shall be based on techno-economics of various options for the construction techniques.

(1) **Geo-technical investigations**

Geo-technical investigations are required for elastic assessment of foundation geology and shall be carried out during investigation stage prior to taking up construction activity. The geo-technical investigations shall include determination of the sub soil type, ground water table etc.

Based on above, the type of foundation system, the bearing capacity, the pile parameters, requirement of soil stabilization/ compaction etc., shall be established.

(2) **Site levelling**

The formation level of the Station shall be kept minimum 1.0 m above the High Flood Level (HFL) of the site.

It is preferable to keep the entire Station at the same level. However, to keep the leveling cost to minimum, different levels may be adopted for various blocks. The optimization of excavation and filling quantities may be done while fixing the levels of different blocks.

(3) **Foundations**

Open foundations or pile foundations or a combination of the two keeping in view the lightly/heavily loaded foundations may be suitably adopted. In certain cases, ground improvement and stabilization methods may also be considered.

The foundations for turbines, boiler feed pumps and other rotating equipment shall be suitably designed and the amplitude of vibrations shall be within the limits recommended by the equipment supplier. To optimize the foundation system of rotating equipment, 3-D finite element analysis may be carried out.

Following loads shall be considered for the design of foundations, as applicable:

(a) Load of equipment
(b) Load of other accessories
(c) Dead load of foundation structure
(d) Vacuum load
(e) Un balance forces
(f) Loss of blade force
(g) Short circuit force
(h) Temperature forces
(i) Torque loads
(j) Frictional and other longitudinal forces
(k) Live loads
(l) Wind and seismic loads

(4) **TG and other buildings**

All buildings shall be designed as RCC or steel framed super structures with masonry or steel cladding. TG building shall have structural steel framework for super structure with metal cladding on exterior face. Other buildings may have RCC or steel framework with masonry cladding of minimum one masonry unit thickness on exterior face. The design of steel structures shall be as per provisions of latest version of relevant IS.

Considering the size, loadings and requirements of construction schedule, composite construction with steel supporting structures and RCC floors may be adopted for the TG and other buildings.

(5) **Structure system**

TG building shall preferably be moment resisting structure in transverse direction and braced in longitudinal direction. Mill and bunker building shall be provided with moment resisting frame having adequate bracings in the transverse direction and braced in longitudinal direction.

The structures shall be designed considering worst load combination of dead loads, super imposed dead loads, imposed loads, earthquake loads, wind loads etc. The superimposed dead loads shall include the loads due to equipment and associated auxiliaries and accessories, duct loads as well as crane loads with impact etc. Seismic forces shall be considered as per site specific seismic parameters.

(6) **Architectural requirements**

Overall architectural character of Station building should be in harmony with natural character of environment, climatic conditions and local landscape. Interior design should be given due consideration. The finishing works shall meet the requirements of aesthetics, durability and functional aspects.

Adequate glazing shall be provided for natural light. Adequate ventilation shall be provided in all the buildings.

(7) **Chimney**

Chimney may be single flue unitized or multi-flue for two or more units.

The height of chimney shall be decided based on MOE&F guidelines and any other stipulation of the CPCB and SPCB in this regard. Provision of chimney shall also be got cleared by Airport Authority of India. The size of flue liner shall be decided based on the exit velocity and temperature of flue gases.

Chimney windshield shall be of RCC construction. The flue liners shall be of structural steel or brick construction provided with suitable thermal insulation. The portion of flue liner above chimney shall be of acid resisting bricks protected by RCC minishell. Chimney shall have internal platforms and internal ladder. The top external portion of windshield shall be provided with alternate bands of red and white colours to meet aviation safety requirements. Chimney shall be provided with liner test port for continuous emission monitoring, lightning protection and grounding system, aviation obstruction lighting and an elevator.

Wind tunnel testing for chimney shall be carried out to optimize the design.

The windshield shall be designed for vertical loading, wind loading, cross wind loading, seismic loading, circumferential wind loading and thermal gradients across the shell.

(8) **Corrosion protection**

Steel structures may be provided with epoxy or polyurethane based painting systems.

Suitable measures shall be provided against corrosion for Stations located in coastal areas. Use of special cements, corrosion resistant steel, protective coatings to both concrete and steel are some of the options which can be considered in such conditions.

(9) **Roads and drainage**

The entire area within the Station boundary shall be well connected with a network of roads and drainage system.

The drains in the Station area shall be designed for maximum rainfall intensity of 50 years frequency.

(10) **Safety provisions**

The safety provisions shall be in conformity with the provisions laid down by National Building Code and other international codes.

PART-C: GAS TURBINE BASED THERMAL GENERATING STATIONS

18. Operating Capabilities

(1) The gas turbine(s) shall be installed alongwith heat recovery steam generator(s) and steam turbine except where intended to be used for emergency, black start or only for peaking duty.

(2) Combined cycle gas turbine (CCGT) module, comprising of gas turbine generator(s) and steam turbine generator, shall give its MCR output at the specified site conditions and the design fuel.

(3) The CCGT module shall be capable of base load operation. However, these shall also be capable of load cycling and two-shift operation.

(4) The gas turbine, steam turbine and all rotating auxiliaries shall be suitable for continuous operation within the frequency range of 47.5 Hz to 51.5 Hz.

(5) The design of the equipment and control system shall be suitable for operation of the CCGT module in automatic load frequency control.

(6) Gas turbine rating (ISO) upto 100 MW shall be provided with black start facility.

(7) The CCGT module shall be designed to give optimum efficiency for the fuel stipulated and other site specific conditions. The gross heat rate as guaranteed by the equipment manufacturer shall not exceed the following values:

Table: I- 6

Gas Turbine rating (ISO)	**Gross Heat Rate of CCGT module** (on HHV basis) in kcal/kWh at ISO conditions with natural gas as fuel at 100% load
20 MW to 30 MW	2250
> 30 MW to200 MW	1825
> 200 MW	1700

19. Gas Turbine and Auxiliaries

(1) The gas turbine and auxiliaries shall comply with latest versions of applicable ISO/ASME codes.

(2) The gas turbine compressor shall have a stable aerodynamic characteristic throughout its operating regime. The operating point in the entire frequency range of 47.5 to 51.5 Hz shall be sufficiently away from surge line so that it is stable at all conditions of load, ambient temperature and blade fouling.

(3) The compressor shall be provided with variable type inlet guide vanes to meet start up/ shutdown requirements, improved part load performance in combined cycle mode of operation and exhaust gas temperature control over a wide range.

(4) Combustion chamber arrangement shall be such as to allow maintenance without dismantling of compressor or turbine section and with minimum dismantling of piping and electrical connections.

(5) NOx control shall be either through dry low NOx combustor or through steam/water injection and shall be able to achieve the NOx level limits stipulated by pollution control authorities.

(6) Combustion system shall be provided with flame detection system for monitoring and protection.

(7) Gas turbine shall be provided with self contained lubrication oil system and control oil system with adequate redundancy for pumps and coolers.

(8) Gas turbine shall be provided with an air intake filtration system along with on line cleaning system to deliver filtered air of acceptable quality to the gas turbine.

(9) Gas turbine generating unit shall be controlled by an electro-hydraulic governing system with 100% back up. All necessary protective devices required for safe operation shall be provided. Further, control system of the gas turbine shall include necessary features to check healthiness of protective devices.

(10) The gas turbine shall be capable of withstanding momentary speed rises upto the over-speed trip limit under transient conditions.

(11) For gas turbines operating on naphtha, mandatory purging/ flushing of liquid fuel delivery system (downstream of injection pump) shall be provided to ensure safety of the plant and personnel. A less combustible/ volatile liquid fuel (distillate 2 or HSD) shall be used during start-up and shutdown.

(12) Gas turbines envisaged for dual fuel operation (natural gas as primary fuel and liquid fuel as back-up fuel) shall be capable of on-load fuel changeover from natural gas to liquid fuel automatically or with manual initiation. Changeover from liquid fuel to natural gas shall be through manual initiation.

(13) All piping, valves and fittings downstream of liquid fuel delivery system and NOx water injection system shall be made of stainless steel of suitable grade to avoid corrosion so as to prevent entry of rust into the combustion chamber and mal-operation of stop/control valves.

(14) Each gas turbine shall be provided with on-line fuel flow metering device to monitor fuel consumption.

(15) **Gaseous fuel conditioning system**

(a) Fuel gas conditioning system of the plant shall be designed to provide required quantity of clean, dry gas at required pressure, temperature and quality suitable for the gas turbine.

(b) The temperature of the gas delivered to the gas turbine shall be at least 20^0C higher than hydrate forming temperature or gas dew point whichever is higher.

(c) A chromatograph and analyzer shall be provided for determining the composition and heating value of the fuel gas.

(d) Design of fuel gas system shall be as per the provisions of the latest version of relevant ANSI Standards or equivalent.

(e) The gas leak detection and protection system shall necessarily be provided for enclosed areas.

(16) **Liquid fuel storage and conditioning system**

(a) Liquid fuel storage capacity shall be provided corresponding to 15 days requirement, if liquid fuel is used as the primary fuel.

(b) Liquid fuel conditioning system shall be designed to provide required quality suitable for the gas turbine.

(c) Liquid fuel storage area shall be at least 90 meters away from the gas turbine.

(d) Liquid fuel unloading, storage and forwarding system shall be designed to comply with all applicable statutory requirements.

20. Heat Recovery Steam Generator (HRSG) and Auxiliaries

(1) HRSG shall be suitable for outdoor installation and shall be constructed to form a gas tight envelope to prevent gas leakage.

(2) HRSG shall comply with IBR requirements.

(3) Gas turbine exhaust plenum shall be designed for proper gas velocity and temperature distribution and effective pressure recovery. The exhaust system design shall take into account very rapid start-up and shutdown rate of the gas turbine.

(4) Arrangement for mandatory purging of gas turbine exhaust system and HRSG shall be provided in order to eliminate chances of explosion (puffing) for combined cycle plants envisaged for operation on liquid fuel firing.

(5) The design of HRSG shall be based on finned tube heat transfer banks of superheaters, evaporators, economisers etc. The fin density shall not be higher than 200 fins/m.

(6) The design of HRSG shall be suitable for direct on line starting along with the gas turbine.

(7) The HRSG shall be designed for single pressure/two pressure/three pressure steam generation based on gas turbine rating and techno-economics.

(8) In the event of loss of feed water, it shall be possible to continue HRSG operation for a short duration till the mode of operation of gas turbine is changed to open cycle or gas turbine is tripped and coasted down.

(9) The gas temperature at HRSG exit, the temperature of condensate entering condensate pre-heater and temperature of feed water entering economiser shall be such as to avoid acid dew point corrosion.

21. Steam Turbine and Auxiliaries

Steam turbine shall be single or multi pressure, condensing type complying with relevant IEC Standards or equivalent. Other requirements stipulated for coal or lignite based thermal generating stations in Part-B of this Schedule in respect of steam turbine & auxiliaries shall be complied with, as applicable.

22. Electrical System

Electrical Systems shall meet the requirements stipulated for coal or lignite based thermal generating stations in Part-B of this Schedule in respect of Electrical System, as applicable. However, in case of smaller size of generators, the neutral may be earthed through resistance or voltage transformer.

23. Control and Instrumentation System

Control and Instrumentation Systems shall meet the requirements stipulated for coal or lignite based thermal generating stations in Part-B of this Schedule in respect of Control and Instrumentation System, as applicable.

24. Station Water System

Station water system which includes clarified water system, cooling water system, de-mineralisation system, service water system, potable water system, waste water treatment system shall meet the requirements as stipulated in Part-B of this Schedule in respect of Station Water System, as applicable.

25. Fire Detection, Alarm and Protection System

Fire detection, alarm and protection system shall meet the requirements as stipulated for coal or lignite based thermal generating stations in Part-B of this Schedule in respect of fire detection, alarm and protection system, as applicable.

26. Civil Works

Civil works shall meet the requirements as stipulated for coal or lignite based thermal generating stations in Part-B of this Schedule in respect of civil works, as applicable. However, stack shall be of steel construction and its height shall meet the requirements of MOE&F and any other stipulation of the CPCB and SPCB in this regard.

PART- D: DIESEL ENGINE BASED THERMAL GENERATING STATIONS

27. Preliminary

Diesel engine based thermal generating stations shall comprise of diesel generating (DG) sets and associated facilities. Such generating stations shall be installed only for the remote areas where it is not feasible to install alternative modes of power generation facility or where it is necessary to install DG set as back up or standby facility.

28. Operating Capabilities of DG Sets

(1) The DG sets shall be capable of base load operation. However, these shall also be capable of load cycling and two-shift operation.

(2) The diesel engine and all rotating auxiliaries shall be suitable for continuous operation within the frequency range of 47.5 Hz to 51.5 Hz.

(3) The design of the equipment and control system shall be suitable for operation of the DG set in automatic load frequency control.

(4) The DG set shall be a self contained unit and skid mounted. These shall be suitable for indoor installations either on pads or on reinforced concrete foundations. All the facilities required for receiving and feeding the inputs such as fuel, lubricants, water, air etc. and the control panel and synchronizing panel shall be provided.

(5) The DG set shall have auto start, auto loading, auto stop features and capable of parallel operation in the power distribution system with synchronizing facilities.

(6) The DG set shall be designed to give optimum efficiency for the stipulated fuel and other site specific conditions. The gross heat rate as guaranteed by the manufacturer shall not exceed the following values:

(a) **Diesel engine generators (four stroke)**

Table: I- 7

DG Set Rating	**Gross Heat Rate (on HHV basis)** in kcal/kWh at 100% load
100 kW to 1 MW	2350
>1 MW to 3 MW	2250
> 3 MW to 10 MW	2100
>10 MW	2000

(b) **Diesel engine generators (two stroke)**

Table: I- 8

DG Set Rating	**Gross Heat Rate (on HHV basis)** in kcal/kWh at 100% load
3 MW to 10 MW	2000
> 10 MW	1950

29. Diesel Engine and Auxiliaries

(1) The diesel engine and auxiliaries shall comply with latest versions of applicable IS/ ISO/ BS or equivalent codes.

(2) Turbo charger, if applicable, shall be of robust construction, suitable of being driven by engine exhaust. It shall draw air through air filter and have adequate capacity to suit engine requirements.

(3) The diesel engine shall be capable of satisfactorily driving the generator at 10% over load at rated speed for one hour in any period of 12 hours of continuous running.

(4) The diesel engine shall be provided with suitable self-starting device.

(5) The diesel engine shall be provided with an air intake filtration system to deliver filtered air of quality suitable for the diesel engine.

(6) An engine driven booster pump shall be provided to deliver the fuel oil from the supply tank through the filters. In addition, an AC motor driven fuel oil priming pump shall be provided to keep the high-pressure system primed for remote and quick starting at any instant.

(7) The diesel engine shall be cooled by engine mounted radiators or remote radiators using closed cycle cooling system. In case of remote radiators, low speed axial fans shall be provided to keep the noise level well within acceptable limits.

(8) The diesel engine shall be provided with micro-processor based control system. The governor shall be electronic type complying with latest version of relevant IS. An over speed trip mechanism shall be provided to automatically shut off fuel in case the set reaches above 10% of rated speed. An engine mounted emergency stop push button shall be provided to stop the engine during emergencies.

(9) The diesel engine shall be provided with self contained lubricating oil system.

(10) Crankcase gases shall be piped outside the engine room so that oil fumes do not accumulate on the engine and radiator.

(11) The diesel engine shall be furnished with exhaust system comprising of efficient silencers, chimney etc.

(12) NOx level, stack height and noise level shall comply with the guidelines laid down by MOE&F and any other stipulation of the SPCB and CPCB in this regard.

30. Liquid Fuel Storage and Conditioning System

(1) Liquid fuel storage capacity shall be provided corresponding to 15 days requirement.

(2) Liquid fuel conditioning system shall be designed to provide required quality suitable for the diesel engine.

(3) Liquid fuel unloading, storage and forwarding system shall be designed to comply with all applicable statutory requirements.

(4) Each diesel engine shall be provided with on-line fuel flow metering device to monitor fuel consumption.

31. Electrical System

Electrical requirements stipulated in Part- B of this Schedule shall be complied with for switchgear, transformers, cables, protections etc. as applicable. However, in case of smaller size of generators, the neutral may be earthed through resistance or voltage transformer.

32. Fire Detection, Alarm and Protection System

Suitable fire detection, alarm and protection system shall be provided for the Station.

SCHEDULE-II

TECHNICAL STANDARDS FOR CONSTRUCTION OF HYDRO- ELECTRIC GENERATING STATIONS

33. Preliminary

This Schedule stipulates the minimum technical requirements for construction of Hydro-Electric Generating Stations for various types of schemes i.e. Run-of-river scheme, Storage scheme, Pumped storage scheme, Canal head scheme etc. with installed capacity of 25 MW and above. For hydro-electric generating Stations having installed capacity less than 25 MW, the stipulations as appropriate, shall apply.

34. General Requirements

(1) The salient features of the project, installed capacity, unit size, location of project and layout, power evacuation arrangement, etc. shall be decided considering the best engineering practices and optimum utilisation of resources.

(2) The Generating Station shall be complete with all infrastructure works, civil works, hydraulic works, hydro-mechanical works and electro-mechanical works. All the equipment and systems required for safe, reliable and prudent construction, operation and maintenance of the Station shall be included. Additional equipment and systems, as required, for the multi-purpose schemes/projects shall also be included.

(3) While designing the H.E. Project, the life of the civil works shall not be less than one hundred (100) years, while that of main electro-mechanical generating equipment i.e turbine, generator, transformers, auxiliaries, etc. installed shall not be less than thirty five (35) years.

(4) The Station shall be designed for unconstrained operation over maximum net head and minimum net head, specified silt conditions wherever applicable, and full range of ambient and other environmental conditions.

(5) The dimensions of the power house, turbine settings, speed rise, pressure rise, run-away speed, etc. shall be governed by the limits specified in relevant IS.

(6) The chemical analysis of water and silt data including the petrographic analysis shall be taken into consideration while designing the turbine, main inlet valve and other auxiliary equipment susceptible to abrasive effects of

silt. All necessary specific provisions such as selection of materials, protective coatings and painting shall be made to resist silt abrasion.

(7) The generating units of rated capacity 50 MW and higher shall be capable of operation in synchronous condenser mode, wherever feasible.

(8) The operation of the unit shall be smooth and quiet. The noise level shall not be more than 90 dBA at a distance of 1 metre from any equipment.

35. Layout Considerations

(1) General layout of the Station shall be developed considering space optimization, functional requirements, future extensions (if envisaged) and provision of space requirements during construction stage. The layout of the Station shall be compact so as to economise on the use of materials.

(2) Adequate maintenance facilities shall be provided as required for assembly, disassembly and handling during maintenance of all important equipments and auxiliaries.

(3) Adequate fire escape staircases / galleries shall be provided in main Station building/Cavern. Each equipment room shall be provided with alternate exits to be used in case of fire / accidents as per requirements of the Factory Act and other statutory requirements.

(4) The dimensioning and layout of the Station shall be as per relevant IS.

36. Operating Capability of the Generating Unit

(1) The unit shall be capable of giving the rated output continuously as specified by the manufacturer at the rated design head and rated discharge without any restriction over the complete range of operating conditions and ambient temperature at site as specified.

(2) The maximum continuous overload capacity of the unit at the generator terminals during the high head conditions or high discharge conditions or both as guaranteed by the manufacturer shall be based on hydraulic parameters of the Station but shall normally not be more than 10% above the rated output of the machine.

(3) The unit and all the associated auxiliaries shall be suitable for continuous operation without any restriction within a frequency range of –5% to +3% (47.5 Hz to 51.5 Hz). All the equipment driven by the electric motors shall give their rated performance even at a power supply frequency of 47.5 Hz.

(4) Adequate provisions shall be made for starting the machine in auto mode upto synchronization by a single command and loading of the unit to full load quickly. The design of the equipment and control system shall permit participation of the unit in automatic frequency control mode.

(5) The unit and all its associated auxiliaries shall be designed for trouble free operation upto maximum rating of the unit for the complete range of operation for active power and reactive power output.

(6) The unit and its auxiliaries shall be designed to operate for the silt levels and its characteristics specified for the project based on the historical water inflow data of the river.

(7) Adequate margins and redundancies shall be provided in unit auxiliaries and station equipment so that the generating unit continues to operate even in the event of outage of a part of the auxiliary system.

(8) The Station shall be equipped with facilities for black start of generating unit in the event of grid black-out conditions.

37. Hydraulic Turbines and Auxiliaries

(1) The hydraulic turbine shall comply with latest versions of relevant IS / IEC standards.

(2) Turbine shall have smooth and quiet operation. The vibrations, pressure pulsations and power fluctuations shall be within the limits specified in relevant standards. The amplitude of the vibrations at the shaft shall not exceed the limits specified in relevant ISO standards.

(3) The type and rotational speed of the turbine shall be selected based on range of head, specific speed, head variation etc. In case two different types of turbines are found suitable for the range of head envisaged (overlapping zone of net head) at a particular site, the selection of turbine shall be based on the techno economic considerations taking into account the aspects such as head variation, civil costs, part load operation, operation and maintenance, efficiency etc.

(4) The rated speed resulting in even number of pair of poles shall be preferred. In case of high silt content, at least one step lower synchronous speed shall be selected.

(5) Before the manufacture of the prototype turbine is taken up, homologous scale model of the prototype turbine shall be made if not already available and tested to demonstrate that the prototype turbine will meet the guaranteed

performance in respect of efficiency, output, smooth operation, pressure pulsations, and other guarantees as stipulated in the technical specifications.

(6) The weighted average efficiency shall be computed based on the efficiencies at various outputs. The weightage factors shall be selected corresponding to the average duration or period (in percentage) in a year, for which the units are expected to be operated at different outputs. The weighted average efficiency obtainable shall not be less than 93% for Francis, 92% for Kaplan & Bulb turbines and 91 % for Pelton, Deriaz and Propeller turbines. The peak efficiency at rated conditions shall be as high as possible and shall be higher than 94%, 93% and 91.5% respectively for these turbines."

The weighted average efficiency of the turbine shall be determined after the installation and commissioning of the generating units on the basis of field acceptance tests on one of the units as per relevant IS / IEC standards.

(7) The minimum load for continuous operation for various types of turbines shall be as under:

Table: II- 1

Type of turbine	**Minimum load for continuous operation (percent)**
Pelton or Kaplan or Bulb	30
Deriaz	40
Francis	50
Propeller	85

(8) The pressure rise and speed rise of turbine shall be within the range specified by relevant Indian standards. For a unit which is one of the several units on a common penstock header system, the permissible percentage of speed rise shall be computed on the basis of one unit operating alone.

(9) The turbine shall be designed to withstand runaway speed of 1.8 times the rated speed for 15 minutes without causing any residual detrimental affect on future operation of the machine. However, critical speed of the machine shall be around 25% higher than maximum runaway speed.

(10) Provision of runner removal from bottom for maintenance shall be made, wherever feasible.

(11) The setting of reaction turbine, i.e. centre line of runner, with reference to minimum tail water level shall be governed by cavitation considerations. Based on the calculations, the center line of the runner may work out to be

either above or below the minimum tail water level. Pelton turbine shall be installed with its centre line at a height of minimum 3 m above the maximum tail water level or as per the recommendations of the manufacturer.

(12) Special care shall be taken to select the material of the under water parts. The materials selected for runner, guide vanes, etc. shall have high wear resistance, corrosion and cavitation resistance. Besides, the use of the material having good weldability shall be considered so that parts can be fabricated and the eroded parts can be repaired easily at site.

(13) As most of the rivers in the Himalayan region carry high silt which erodes the runner and under water parts of a turbine at a comparatively faster rate, appropriate protective coatings shall be provided for these parts of a turbine in order to minimize silt erosion, wherever necessary.

(14) The guide-vanes, runner, discharge ring and other hydraulic passages shall be designed for a life of 8000 hours against excessive pitting caused by cavitation.

(15) The pump turbine shall be capable of giving output higher than the rated output while operating in the turbine mode. The pump turbine shall be designed giving preference to its operation in "Turbine Mode" and the best efficiency shall be obtained while operating at design head conditions and delivering the rated output.

(16) The centre line of a pump turbine shall be fixed corresponding to pumping operation.

38. Governing System

(1) Microprocessor based digital governing system shall be used for regulating the flow of water to the turbines for the control of active power (MW) thus providing the requisite speed/frequency control and load control. The speed sensing device shall be provided with the requisite redundancy. The performance requirements of the governing system shall be governed by relevant IS / IEC standards.

(2) High pressure oil system shall be provided for each turbine for the operation of wicket gates/nozzle/deflector servomotors through governors and for the control of main inlet valve (MIV). Piston type accumulator with nitrogen bottles shall be used for pressures higher than 60 kg/cm^2.

(3) Separate oil pressure systems shall preferably be used for the control of turbine and the control of MIV.

(4) The sizes of various components of oil sump tank and pressure receiver shall be calculated as per the relevant IS/ IEEE standards. The oil volume below its machine shutdown level shall be sufficient to perform 3 full operations of the servomotor viz. Close-Open-Close with oil pumps being out of operation.

39. Spherical Valve and Butterfly Valve

(1) The spherical valve and butterfly valve shall comply with the requirements of latest versions of relevant IS / IEC standards.

(2) The spherical valve shall be provided for safe emergency closure in case of turbine speed increasing to runaway speed.

(3) The valves shall have service seal on downstream side and maintenance seal on upstream side.

(4) The opening and closing of butterfly valves shall normally be done under balanced water condition. Suitable number of air release valves shall be provided at the appropriate location on the downstream side to allow the air trapped in the penstock to escape when it is filled with water through the bypass valve and for supplying / admitting the air when the valve is suddenly closed.

40. Mechanical Auxiliaries

(1) **Electric overhead travelling (EOT) cranes**

(a) The EOT cranes shall comply with the requirements and standards of latest versions of relevant IS / IEC standards. The category of cranes shall be M5 as per relevant Indian standard. The span of the crane shall be fixed in such a way that the travel and lift of the main and auxiliary hooks of the crane as well as the hook limits shall be adequate for the assembly and disassembly of the main equipment in the power house. The lift above the service bay (upper limit) shall be adequate to hoist and carry the rotor of the generator and to assemble and disassemble the transformer. The lift below the service bay (lower limit) shall be fixed in such a way as necessary for assembly and disassembly of the turbine.

(b) The hook capacity shall be taken as 10% more than the maximum weight to be lifted inclusive of the weight of the lifting beam. If the maximum weight to be lifted is more than 300 Tonnes, two cranes each of equal capacity shall be deployed to lift the heaviest package in tandem operation.

(c) The provision of radio remote control and variable voltage variable frequency (VVVF) drive for various crane motions for the purpose of precision speed control shall normally be made for cranes having capacity 100 Tonnes and above.

(d) The radio remote control equipment, wherever provided shall conform to all applicable Government rules and regulations. The frequency of operation shall be in the requisite frequency band as per relevant standards.

(2) **Cooling water system**

(a) The cooling water requirements of generator air coolers, shaft seal, turbine and generator bearings of each unit and generator transformer shall be met either by pumping the water drawn from the tail pool / draft tube or providing a penstock tapping for the same. The penstock tapping shall not be considered in case of high head installations i.e. where the penstock pressure is more than 10 kg/cm^2. If the penstock tapping results in a pressure of upto 10 kg/cm^2, a suitable pressure reducer depending on the requirement of net cooling water pressure (usually 3 to 5 kg/cm^2) shall be provided. However, as far as possible the penstock tapping for cooling water requirement shall be avoided.

(b) In the projects where rivers have silt laden water, closed circuit cooling water system shall be provided.

(3) **Dewatering and drainage system**

(a) Suitable dewatering submersible pumps shall be provided to pump out the water trapped between the penstock gate/main inlet valve and draft tube gate in case of Francis and Kaplan turbines to the dewatering sump when maintenance on the turbine of any unit is required to be carried out. The capacity of the pump shall be chosen in such a way that a single unit can be dewatered within 8 hours operation without raising the level in the sump.

(b) All the drainage water within the power house shall be collected inside the drainage sump constructed near the dewatering sump. The drainage water shall be allowed to flow out to the tail race above the maximum tail water level using pumps, if required.

(c) The drainage and dewatering sumps shall be inter-connected by means of gate valve and non return valve which allows the flow of water from the drainage sump to the dewatering sump only. The spindle of the gate valve shall be extended up to the turbine floor so that it is possible to operate it from the turbine floor.

(d) A suitable pressure hatch shall be provided to prevent any flow of water from dewatering sump into the power house. Drainage sump shall not have any pressure hatch.

(4) **Ventilation and air-conditioning system**

(a) A ventilation and air-conditioning system shall be provided to achieve proper working conditions inside the power house complex, to serve the purposes such as prevention of temperature stratification, removal of contaminated air, removal of waste heat from equipment as well as provide fresh air necessary for human comfort with regard to temperature, humidity, and oxygen content, and to extract/force out smoke and other toxic gases during fire.

(b) Suitable system for circulation of natural air and exhaust shall be provided as a minimum requirement. Cooling of air wherever required may be provided by evaporating, water cooled cooling tubes or chiller units.

(c) The control room, relay room, PLCC room, offices, reception, conference room, etc. are normally recommended to be air-conditioned. The conditioned air shall be about 25^0C at around 50% relative humidity for comfort conditions. A choice of installation out of 3 different types of installations i.e. window or split type, package type or centralized air conditioning plants shall be made on the basis of the required tonnage and suitability of the installation at that particular location.

(5) **HP and LP compressed air system**

(a) High pressure (HP) compressed air system shall be provided to meet the compressed air requirement of turbine governing system and MIV. The pressure of HP air compressor shall be 1.1 times the governor working pressure. However, the HP compressed air system shall not be required in case the high pressure nitrogen system has been provided for turbine governing system and MIV.

(b) Low-pressure (LP) compressed air system shall generally be rated at 7.0 kg/cm^2 to meet requirements such as inflatable rubber seal of shaft glands, operation of pneumatic tools, cleaning, generator braking and jacking, boosting pressure in the fire protection hydro-pneumatic tank, pneumatic detection line for the operation of deluge valve provided for the generator transformer, etc.

(6) **Power house lift**

The lift and its associated equipment shall comply with the requirements of latest versions of relevant IS. A minimum of one lift shall be provided in the power house besides two sets of staircases for the movement of persons/ goods.

(7) **Oil handling and purification system**

(a) The insulating oil required in the generator transformers for the hydro station shall conform to relevant IS. The type of turbine oil used as a working fluid in speed regulation system and as a lubricant and a coolant for thrust and guide bearings shall be as per the recommendations of the equipment manufacturer.

(b) The oil handling system for each grade of oil shall incorporate two tanks (one for pure oil and another for used oil), associated piping and control equipment.

(c) The oil handling facilities shall be located within the power house or in an isolated building outdoors. To convey the oil to the turbines, generators and transformers, suitable oil pipes shall be laid within the power house. Portable type pumps and purifiers and standard oil drums shall be used for small hydro-electric stations.

(8) **Fire fighting system**

(a) *General*

(i) A comprehensive fire detection, alarm and protection system shall be provided for the Station. The fire protection system as well as hydrant system shall be designed complying with the guidelines of Tariff Advisory Committee (TAC) or NFPA as applicable.

(ii) All major and minor fire risks in the Station such as transformers, cable galleries/shafts, control rooms etc. shall be protected against the fire by suitable automatic fire protection systems. The state of the art automatic fire detection and alarm system shall be provided to facilitate detection of fire at the incipient stage and warning to fire fighting staff.

(iii) Portable and mobile fire extinguishers shall be provided to extinguish a fire in the initial stage to prevent its spread.

(b) The transformers or reactors of 10 MVA and higher rating or oil filled transformers or reactors with oil capacity of more than 2000 litres shall be provided with automatic high velocity water spray system as per relevant IS or Nitrogen injection based fire protection system. The transformers or reactors of 220kV or higher voltage may preferably be provided with Nitrogen injection based fire protection system in addition to automatic high velocity water spray system.

(c) The provision shall be made for water sprinkler system for oil plant rooms, especially in an underground power house. In addition, provision shall also be made for fire hose cabinets/hydrants inside the power house as well as for the transformer area. The capacity of overhead / pressurised water tank shall be adequate to meet the fire water requirement for one generator transformer for 40 minutes, plus operation of one hydrant for 60 minutes. Two nos. of fire pumps, each capable of pumping water to fill the overhead/ pressurised water tank in reasonable time shall be provided.

(9) **Equipment for mechanical workshop**

Mechanical workshop equipment shall be provided for essential maintenance work and on-site repairs. The standard workshop equipment like centre lathe, universal milling machine, pedestal drilling machine, pedestal grinding machine, hacksaw machine, fitters, benches / racks, miscellaneous measuring and cutting tools etc. shall normally be provided.

41. Electrical System

(1) **General requirements**

(a) For the purpose of design of equipment or systems, an ambient temperature of 40^0C or higher as applicable to Station site and relative humidity of 95% shall be considered.

(b) All equipments shall be suitable for rated frequency of 50Hz with a variation of -5% and +3%. The overall system shall be designed considering maximum voltage variation and combined variation of voltage and frequency as specified in Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007.

(c) The telecommunication system shall be based on optical fibre or PLCC or both. Owner's telecommunication equipment provided to transmit the required data of the Station to the procurer of electricity, Regional/ State Load Despatch Centre and Transmission Company shall have matching equipment and compatible communication protocol with the receiving end.

(2) **Generator/ generator-motor**

(a) General

(i) The generator shall comply with the requirements of the latest versions of IS / IEC standards.

(ii) Insulation shall be of thermal class F for the stator and the rotor windings with temperature rises limited to that of thermal Class B as per relevant IS / IEC standards.

(iii) The generator shall be capable of safely withstanding the maximum stresses during normal operation, run-away speed conditions, two phase and three phase short circuit conditions, single phase earth fault, 180 degree and 120 degree out of phase synchronization, magnetic unbalance with 50% of the poles short circuited within the speed range of 1.3 times the rated speed, brake application, etc.

(iv) The construction of the generator shall be such that the rotor poles and stator coils can be handled out or in without removal of the rotor and without disturbing the upper bearing bracket. The rotor poles shall be interchangeable.

(v) The output of motor generator shall match with the input required for pumping operation in the operating head range.

(vi) The generator rated speed shall match the rated speed of the turbine or the pump-turbine. A rated speed resulting in even number of pair of poles shall be normally preferred.

(vii) The current flowing in stator slot shall be limited to 3000-6000 Amperes with current through individual coil being limited to approximately 3000 Amperes.

(viii) The power factor and the requirements of reactive power capability shall be specified as per requirement of Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007.

(ix) Surge arresters of suitable rating shall be provided for surge protection of generators.

(x) Resistance temperature detectors (RTD) / thermocouples or any other type of temperature sensors at suitable locations for temperature monitoring of stator core, stator winding and bearings shall be provided. Suitable arrangement for rotor winding temperature monitoring shall also be provided.

(xi) The inertia of the machine shall be adequate to meet the transient stability requirements imposed by the interconnected electrical power system to limit speed rise and shall not have such a value which will cause the machine natural frequency to be in resonance with the expected frequency of draft-tube hydraulic surges. A margin of approximately 25% shall be provided for this.

(xii) Weighted average efficiency based on the computed efficiencies at various outputs for which the generator is expected to operate shall be more than 98%.

(xiii) Dynamic braking shall be provided for generators in addition to mechanical brakes.

(b) Bearing Arrangements

(i) Combined thrust and upper guide bearing mounted on a top bearing bracket above the rotor and lower guide bearing below the rotor shall generally be used for small diameter, long core, high speed machines. For medium to high capacity machines having low speed, combined thrust and guide bearing mounted on a separate bearing bracket located below the rotor and an upper guide bearing installed above the rotor on a separate, light-weight bracket mounted on the top of the stator frame shall be provided. The arrangement of combined thrust and guide bearing mounted on a separate bearing bracket located below the rotor shall be used for low to medium capacity machines having low speed.

(ii) The horizontal mounted hydro-electric machines shall be provided with the journal type bearings. The number of journal bearings shall vary depending upon the machine output, speed, diameter, core length, etc.

(iii) The limiting temperature of the thrust bearing metal of hydro-electric machines shall be 80° C. The guide bearing temperature limit shall be 70° C.

(c) Fire Protection System for Generator

Either water based or CO_2 type of fire suppression system shall be provided. A water based system shall be adopted in underground power stations because release of CO_2 gas in an underground installation shall be hazardous.

(d) Generator Busduct

(i) The generator busduct shall comply with the requirements of the latest versions of relevant IS / IEC standards. Generator busduct shall be segregated or isolated phase type. Busduct rated more than 3150 Amps. shall be isolated phase type. The isolated phase ducts shall be preferred over the segregated phase bus ducts. Generator Busduct rated more than 6000 A shall be continuous isolated phase type. A hot air blowing system or air pressurization system shall be provided to prevent moisture deposition in case of isolated phase ducts while space heaters may be provided in case of other busducts.

(ii) The busduct shall be designed to carry maximum continuous current under normal site conditions without exceeding temperature rise limits. Based on these requirements standard size of busduct as per relevant IS / IEC standards shall be used.

(iii) The bus assembly shall be designed to mechanically withstand a rated continuous current as well as the specified short–circuit current without damage or permanent deformation of any part of the bus structure.

(iv) The surge arrester and voltage transformer (SAVT) cubicle shall meet the requirements of relevant IS / IEC standards.

(e) *Neutral Grounding Terminal Equipment*

(i) Neutral grounding equipment shall be designed taking into account the maximum permissible operating voltage of the generator, voltage rise on load throw off (subsequent to detection of earth fault) field suppression time, ferro-resonance, etc. System earthing shall be such that it shall be possible to provide earth fault protection with proper discrimination.

(ii) All large hydro-electric machines having a wye-connected stator winding with the neutral brought out of the machine housing shall be grounded via a high-resistance circuit consisting of a single-phase grounding transformer connected between the generator neutral and ground having a standard, high voltage rating approximately equal to 1.5 times the maximum machine phase-to-ground terminal voltage rating. A resistor shall be connected across the secondary terminals of the grounding transformer.

(f) *Instrument Transformers*

(i) The current transformers shall preferably be window type fitted around the bus conductors for meeting the protection and measuring requirements.

(ii) The voltage transformers shall be located in separate cubicle for each of the three phases and mounted in withdrawable cabinets.

(iii) The surge diverters and/or the surge capacitors shall be provided in the same cubicle as that of the voltage transformers with suitable barriers.

(g) *Continuous On Line Machine Condition Monitoring Systems*

The following monitoring equipments/systems for prediction of abnormality and preventive action shall be provided for the generating units rated for 100 MW and above:

(i) *Partial discharge monitoring (PDM)*

A partial discharge analyzer (PDA) shall monitor the partial discharge activity of the machine winding, indicating the condition of winding insulation systems. The system shall consist of permanently mounted partial discharge sensors (capacitive couplers) on the line and neutral windings and portable or permanently installed test equipment.

(ii) *Air gap monitoring*

In order to provide high degree of dimensional stability, online air gap monitoring system shall be provided. A uniform air gap under all the conditions of operation below a tolerance of ±10% shall be maintained.

(iii) *Vibration monitoring*

The displacement of the bearings while the units are running shall be monitored by using on-line vibration monitoring equipment for replicating the forces acting on the rotor.

(3) **Excitation system**

(a) Static high initial response rectifier excitation system shall generally be used. Static rectifier excitation system shall obtain the necessary electrical power directly from the terminals of the generator.

The system shall consist of a power transformer, thyristor control element, electronic regulator and de-excitation unit.

(b) The capacity of the excitation system shall be adequate to supply continuously 1.1 times the excitation current and voltage required by the generator at its 100% rated output and 100% rated voltage and also for supplying twice the excitation current required by the machine at its 100 % rated output and 110% rated voltage for a duration of one minute.

(c) The excitation system while operating at its maximum output, terminal voltage, power factor and speed shall be capable of changing from rated field voltage to 90 percent of ceiling voltage within 25 milliseconds for a sustained drop in generator terminal voltage of 5 percent.

(d) The number of bridges shall be such that one bridge is always available as redundant. With the failure of two bridges it shall be possible to continue operation at reduced load. The rectifier PIV (peak inverse voltage) rating shall not be less than four times the maximum RMS voltage of the input.

(e) All the performance requirements of the automatic voltage regulation (AVR), power system stabilizer (PSS) shall be in accordance with Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007 and Central Electricity Authority (Grid Standards) Regulations as and when they come into force.

(4) **Generator step-up transformers**

(a) The generator transformers shall comply with the requirements of the latest versions of the relevant IS / IEC standards.

(b) Water cooled transformers, wherever feasible, shall be preferred for hydro power Stations, and the type of cooling shall be generally oil forced, water forced (OFWF)/ oil directed, water forced (ODWF). In case, provision of water cooling is not feasible, oil forced, air forced (OFAF) type generator transformers shall be provided.

(c) Selection of single phase or three phase transformers for hydro power Stations shall be governed by the transportation limitations and shall be finalised considering the status of load carrying capacities of bridges, culverts etc. enroute.

(d) Generator Transformer shall be suitable for continuous operation at rated MVA on any tap with voltage variation in accordance with relevant IS / IEC standards.

(e) The generator transformers shall be provided with two complete independent sets of cooling equipment each with 100% capacity.

(f) Provision of "Off-circuit" tap changer shall be made for generator-transformers of conventional generating units. On load tap changer may be considered for pumped storage schemes having reversible units. The range of operation for the tap changer shall be governed by the power system requirements.

(g) Surge arrester shall be provided on the high voltage side of each transformer. The surge arrester characteristics, their numbers and exact locations shall be decided based on the insulation co-ordination studies.

(h) Insulation levels for the transformer windings and bushings shall comply with the requirements indicated in Table: III- 5 at clause 47.

(i) Fire walls shall be provided wherever required as per the guidelines of BIS.

(j) The generator transformers having three phase rating of 120MVA and above shall be provided with on line dissolved/ evolved gas analyzer system.

(k) Short circuit withstand test shall be conducted on one of each type and rating of generator- transformers to validate the design and quality unless such test has been conducted within last five years on transformer of same design. In case there is a change in design before five years, the new transformer design shall be validated by carrying out short circuit withstand test.

(5) **Unit auxiliary and station auxiliary AC supply systems**

(a) *Unit Auxiliary A.C. Supply System*

The auxiliary supply system of each generating unit shall be provided with unit auxiliary transformer to feed the loads of the unit. The unit auxiliary transformers, one for each unit, shall be supplied power from the unit's own generation. The essential load consists of mainly cooling water pump motors, excitation and AVR cooling fans, space heaters and OPU, etc. The capacity of a UAT shall be selected based on the consideration that it is able to continuously cater to the requirement of all auxiliaries of the respective unit. During the starting and stopping of the units, these unit auxiliaries shall be supplied power from the station auxiliary A.C. supply system.

(b) *Station Auxiliary A.C. Supply System*

(i) The station auxiliary A.C. supply system shall be designed to provide a high degree of reliability, continuity of service and primarily to supply uninterrupted AC supply to station auxiliaries during normal operation and unit auxiliaries during starting and stopping of the unit.

(ii) The station supply loads for various equipments shall be determined and normal maximum demand shall be calculated at a diversity factor of 0.75. The availability of input supply shall be ensured from the sources independent of station generation. In addition, adequate provision for meeting load of auxiliaries for one unit during starting and / or during the stopping of the unit shall also be kept and for this purpose the UABs shall be connected to station auxiliary boards through tie breakers.

(iii) Two nos. of Station Service Transformers of equal capacity; one main and other as standby shall be provided for supplying power to the station service board feeding power to the station auxiliaries. In the event of A.C. supply failure, the station load shall be supplied by diesel generating set(s) of suitable capacity connected to the station service board (SSB). The station service transformers, DG sets and SSBs shall be located at higher level.

(iv) The various auxiliary systems shall incorporate appropriate auto transfer scheme/manual changeover to bring in the reserve supply source as required to prevent the loss of unit(s) and to ensure the equipment safety.

(c) Each switchgear, motor control centres (MCCs), distribution boards (DBs) shall be fed by 2x100% transformers/ feeders and these shall be rated to carry the maximum load expected to be imposed.

(6) **DC supply system**

(a) The DC Supply Systems for hydro power stations shall comprise of Batteries, Battery Chargers and DC Distribution Boards. The standard voltage rating for the DC system shall be 24V / 48V for computerized control system and 220V /110V for control and protection etc.

(b) The battery capacity shall be decided with 10% design margin and ageing factor as applicable. The battery shall have sufficient capacity to provide 3 hours requirement of uninterrupted emergency illumination independently.

(c) DC system shall comprise of two DC battery sets (both battery sets of full capacity) each with one float –cum- boost charger.

(d) The float cum boost battery charger as well as its automatic regulator shall be of static type. It shall have a facility of both auto as well as manual control in both the float and boost modes.

(e) DC distribution boards shall be designed to supply the various station loads like normal continuous load, emergency lighting load, excitation current for field flashing of generators and indicating lamp loads.

(f) The DC batteries, battery chargers, and DCDB shall be placed at a floor higher than that of machine hall.

(7) **Grounding system**

(a) The grounding system shall be designed for a life expectancy of at least fifty (50) years, for maximum fault current of the system. MS flats / rods shall generally be used as main ground mat. The touch and step potentials shall be maintained within acceptable limits as per relevant IEEE/ IS/ IEC standards.

(b) Grounding and lightning protection for the entire power Station and other areas or buildings shall be provided in accordance with relevant IS/ IEEE standards.

(c) Separate, distinct grounding system, if feasible, shall be provided for power house, switchyard and remote structures such as control buildings, communication buildings, spillway gate structures, storage buildings, etc. and other civil/ hydraulic structures inter-connected, if required.

(d) Special attention shall be made for grounding of HV-GIS equipment, computer networks and communication equipment as per the manufacturer's recommendations.

(e) All equipment shall be grounded at two points for reliability.

(f) Provision at appropriate locations shall be kept for measurement of grounding resistance at regular intervals.

(8) **Illumination**

(a) Adequate illumination shall be provided as per relevant IS. Apart from normal AC illumination system, emergency AC and DC illumination at strategic locations shall also be provided. DC illumination shall be provided to enable safe movement of personnel and access to important control points during an emergency.

(b) Energy conservation measures shall be adopted, while designing the lighting system. Sodium vapour (high pressure) or other more efficient latest technology lighting fixtures shall be preferred for outdoor lighting of areas such as switchyards, spillways and dams, parking areas etc. Automatic switching via photo electric cells can be adopted for outdoor lighting to optimise power consumption.

(c) Metal halide fixtures shall be used for certain indoor areas such as erection bay, generator hall, machine hall, turbine pit and other high bay areas where proper colour rendition is needed and long-life is essential.

(d) Incandescent lamps shall be used only for battery powered emergency lights and for certain places where lights shall not be turned on continuously or where fluorescent fixtures are impractical.

(9) **Power and control cables**

Cables shall be flame retardant, low smoke (FRLS) type. Directly buried cables shall be essentially armoured type. Cables shall be derated for the site ambient and ground temperatures, grouping and soil resistivity as per relevant IS.

(10) **Cable trenches and cable racks**

A comprehensive philosophy of segregation/ separation of cables of different types / voltages shall be adopted for cable installation. For laying of cables in a power house, a broad based system involving cable gallery, tunnels, trenches, cable racks, shafts etc. shall be provided. In outdoor switchyards, a cable trench system shall be provided. The main considerations/ practices shall be:

- Segregation and proper spacing shall be maintained

- Control, auxiliary low voltage (upto 1.1kV) power and medium voltage (above 1.1kV and upto 66kV) power cables shall be laid in separate trays.

- Proper attention shall be given to ventilation / heat dissipation aspects particularly in case of HV cables.

(11) **Electrical protection system**

(a) Fully graded protection system with requisite speed, sensitivity and selectivity shall be provided for the entire Station.

(b) Protective relays shall be used to detect electrical faults, to activate the alarms and disconnect or shut down the faulted apparatus to provide for safety of personnel, equipment and system.

(c) Electrical faults shall be detected by the protective relays arranged in overlapping zones of protection.

(d) All generating units shall have standard protection system to protect the units not only from faults within the units and within the Station but also from faults in sub-stations and transmission lines. For the generating units with a rating of more than 100MW, protection system shall be configured into two independent sets of protection (Group A and B) acting on two independent sets of trip coil fed from independent D.C. supplies, using separate sets of instrument transformers, and segregated cables of CTs/VTs. The main protection relays for the generators, motors, transformers and the transmission lines shall generally be of numerical type.

(e) All relays used shall be suitable for operation with CTs secondary rated for 1 Amp or 5 Amps as per relevant IS / IEC / IEEE standards.

(f) The protections to be provided for the generating units as a minimum are shown below:

(i) *Generator*

Table: II- 2

Protection Functions	Size of Generating Unit		
	Small (< 10 MVA)	Medium (10-100 MVA)	Large (> 100 MVA)
Differential	Y	Y	Y
95 % stator E / F	Y	Y	Y
100 % stator E / F	N	Y	Y
Inter turn faults	Y	Y	Y
Backup impedance	N	Y	Y
Voltage controlled O / C	Y	N	N
Negative phase sequence	Y	Y	Y
Loss of excitation	Y	Y	Y
Reverse power	Y	Y	Y
Pole slipping	N	N	Y

Overload	Y	Y	Y
Over voltage	Y	Y	Y
Under frequency	Y	Y	Y
Dead machine	N	N	Y
Rotor earth fault	Y	Y	Y
Overfluxing	N	Y	Y

Y: Protection function to be provided.
N: Protection function need not be provided.

(ii) *Generator transformer*
- Generator transformer differential protection
- REF protection
- IDMT O/C protection
- Neutral grounding back-up protection (IDMT O/C relay)
- Overfluxing protection
- Monitoring of Insulation of L.V. bushing
- Buchholtz relay
- Winding temperature protection
- Oil temperature protection
- Oil level low
- Pressure relief valve
- Cooling system failure

(iii) *Generator and generator transformer*
- Overall differential protection

(iv) *Unit auxiliary transformer*
- Restricted E/F protection
- Instantaneous and IDMT O/C protection
- O/C and E/F / neutral backup protection
- Winding temperature protection

(v) *Station auxiliary transformer*
- Restricted E/F protection
- Instantaneous and IDMT O/C protection
- O/C and E/F / neutral backup protection
- Winding temperature protection

(vi) Excitation transformer
- Restricted E/F protection
- Instantaneous and IDMT O/C protection
- O/C and E/F / neutral backup protection
- Winding temperature protection

(g) The protection functions shall be subdivided into two groups each having independent and capable of providing uninterrupted protection to meet the exigency when one of the protection groups fails. The protection functions shall be divided in two groups as shown below:

Table: II- 3

Group A	Group B
(i) *Generator*	
Generator differential	Overall differential
Back-up impedance (or alternatively over current/under voltage)	95% stator earth fault
Negative phase sequence	Pole slipping*
Overload protection	Loss of excitation
100% stator earth-fault	
Rotor earth fault	Under frequency
Reverse power	Reverse power
Over voltage	Over fluxing
Inter-turn fault	
(ii) *Generator transformer*	
Transformer differential	Over current
Earth fault over current	Restricted earth fault
(iii) *Unit auxiliary transformer*	
Earth fault over current	Over current Restricted earth fault

* Pole slipping protection shall be provided for unit size greater than 100MVA.

Note: The dead machine protection to be provided for unit size greater than 100MVA shall not be part of above protection group and would be provided in a separate protection panel.

(h) Relevant IS/ IEC/ IEEE standards shall be generally applied for protection of generators, transformers and motors.

(i) *Motors*

AC Motors shall be squirrel cage / slip ring induction motors suitable for direct on line starting while crane duty motors shall be squirrel cage type induction motors with variable voltage and variable frequency drive as applicable. DC Motors shall be shunt wound.

Temperature rise for Air cooled motors shall be limited to 70^0C by resistance method for both class B and F insulation. All motors shall be either totally enclosed fan cooled (TEFC) or totally enclosed tube ventilated (TETV).

(j) *Diesel Generator*

The provision of the diesel generators shall be made to meet the requirement of emergency power supply for essential station services and black starting of the units considering the starting up of one generating unit at a time during black start condition. In the event of normal station service power disruption and for standby supply during grid black-out condition, it shall be ensured that the essential auxiliaries of all the units are fed from diesel generator and non-essential loads are automatically tripped.

42. Control, Protection and Instrumentation

(1) **General**

The control and instrumentation system provided for the Station shall be consistent with modern power Station practices and in compliance with all applicable codes, standards, guidelines and safety requirements**.**

(2) **Control and protection system**

(a) Unit and station control system shall be microprocessor / computer based distributed digital control system interconnected through fibre optic cables or copper cables (for distances less than 100 metres) having hundred percent redundancy**.** Each generating unit shall have independent programmable logic controller with requisite redundancies. The control of each unit from the unit control board shall be independent of each other.

(b) Depending upon the control philosophy adopted for the hydro plant, the following control, operation and monitoring points shall be provided for the generating units:

(i) Manual control of individual equipment from control cubicle/ control boxes located near the equipment.

(ii) Manual and automatic control from unit control board (UCB) located near the unit at machine hall.

(iii) Automatic operation from station control centre located in the power house control room.

(iv) Provision shall be made for automatic operation of plant from remote despatch centre. It shall be compatible with the station control centre and shall ensure transfer of data/communication signals.

(c) The control system shall be divided in the following groups with independent controls:

(i) Generating unit controls
(ii) Common controls (for control of common auxiliaries)
(iii) Station controls (for station auxiliaries)
(iv) Switchyard controls
(v) Dam gate controls (wherever applicable)

The above groups shall be interconnected and also controlled from the control room through computerised control system (CCS). The type of interconnection with remote equipment shall be through a reliable communication mode.

(d) The following modes of unit start / stop controls shall be provided:

(i) Automatic start/stop
(ii) Auto – inactive
(iii) Step by step starting

(e) As a backup to the microprocessor based controls, a relay based back up shut down may also be provided for parallel shut down in case of emergency / protection master trip relay operation.

(f) A centralized control center for the control of complete power Station shall be installed in power house control room. Computer based man machine interface (MMI) shall be installed with operation control stations having video display units, key board, printers, etc. for the operation of power Station. For complete overview of complete Station, a passive mimic board or interconnected large video screen (LVS) shall be provided in the control room.

(g) The emergency stop push button for each unit for unit shut down shall be provided in the control room. The emergency push button shall be hard wired from unit control board.

(h) An automatic synchronizer with double channel design having frequency and voltage matching including one set of synchronizing equipment for manual synchronizing shall be provided in each UCB. A common manual synchronizing set shall be provided for smaller sets.

(i) Provisions for the historical storage / long term storage and retrieval of data shall be made.

(j) The computerised control system shall be compatible with relevant IS/ IEC standards for communication with protection panel, LDC and other PLCs.

(k) Independent and reliable 230 V AC UPS with 30 minutes backup with requisite redundancy shall be provided for computerised control system equipment located in control room and DC power supply system with minimum of 2 hours battery backup for controllers, input/ output cards, control network etc. shall be provided.

(3) **Instrumentation**

(a) Primary instruments like transmitters, thermocouples, RTDs or other types of sensors, gauges, flow elements, transducers etc. shall be provided.

(b) Microprocessor based vibration monitoring and analysis system shall be provided for critical rotating equipments.

43. Provisions Required for Protection of Power House Against Flooding

Following provisions shall be made for protection of Power House against flooding:

(i) In addition to drainage and dewatering pumps as per clause 40(3), suitable number of submersible pumps with provision for automatic starting by means of level switches shall be provided at main inlet valve (MIV) floor.

(ii) The control panels for dewatering and drainage pumps shall be located at a floor higher than that of turbine floor.

(iii) Suitable float switches shall be provided in power house building to give closing signal to the MIV in the event of inundation of power house due to any reason including penstock rupture or leakage in penstock or for some other reasons.

(iv) The station service transformers and station service boards shall be located at higher level.

(v) The excitation cubicles, unit control panels, unit protection panels etc. shall be located in the machine hall to the extent possible.

(vi) The DC batteries, battery chargers and DCDBs shall be placed at a floor higher than that of machine hall.

(vii) Provision shall be made for operation and control of surge shaft gates from remote for quick isolation of water conductor system in case of failure of other line of defence / protection.

(viii) Provision of individual hoisting mechanism for draft tube gates of each unit may be considered for quick closing. The draft tube gates shall be capable of closing under unbalanced condition of water pressure.

SCHEDULE- III

TECHNICAL STANDARDS FOR CONSTRUCTION OF SUB-STATIONS AND SWITCHYARDS

44. Preliminary

This Schedule stipulates the minimum technical requirements for construction of Sub-stations and Switchyards in following three parts:

Part - A: Sub-Stations and Switchyards (66kV and above)
Part - B: Sub-Stations (33/11 kV, 33/22kV and 22/11kV)
Part - C: Distribution Sub-Stations (33/0.4kV, 22/0.4kV, 11/0.4kV)

PART-A: SUB-STATIONS AND SWITCHYARDS (66KV AND ABOVE)

45. General

(1) The rated rupturing capacity of the circuit breaker to be installed at any new sub-station or switchyard shall be at least 25% higher than the calculated maximum fault level at the bus to take care of the increase in short circuit levels as the system grows. The rated breaking current capability of switchgear and breakers to be installed at different voltage levels, based on available capacities of the breakers, shall be considered as shown in Table: III- 1.

Table: III- 1

66 kV	31.5 kA (for 1 sec.)
132 kV	31.5 kA (for 1 sec.)
220 kV	40 kA (for 1 sec.)
400 kV	40 or 50 kA (for 1 sec.)
765 kV	40 or 50 kA (for 1 sec.)

If the fault level at a sub-station exceeds or is likely to exceed the permissible fault level with the addition of more generators and termination of new transmission lines, adequate measures to limit the fault level like sectionalisation of the sub-station bus or installation of series reactors on the line or bus at the respective sub-stations shall be resorted to.

(2) The transformation capacity of any single sub- station for meeting loads at different voltage levels shall not normally exceed the values brought out in Table: III- 2.

Table: III- 2

765 kV	4500 MVA
400 kV	1500 MVA
220 kV	500 MVA
132 kV	150 MVA
66 kV	75 MVA

(3) The size and number of interconnecting transformers (ICTs) at a sub- station shall be planned in such a way that the outage of any single unit does not overload the remaining ICT(s) or the underlying transmission system.

(4) The location, layout, design and construction of the new installation shall provide for automation and computerized coordinated operation through Supervisory Control and Data Acquisition System (SCADA) and Energy Management System and for future expansion.

(5) The sub-station or switchyard shall be designed and constructed to give a life of not less than 25 years.

46. Design Considerations for Sub-stations and Switching Stations

(1) The sub-station or switching station can be a conventional Air Insulated Sub-station (AIS) or a Gas Insulated Sub-station (GIS). The factors to be taken into account for designing sub-stations shall be as under.

(a) The choice of site for a sub-station or switchyard shall be based on technical, economic and environmental factors. The approximate location shall be determined on grid considerations. The new sub-station shall enhance the operational flexibility, system reliability and transmission or transformation capacity after becoming a part of the network.

(b) Land area required shall be considered based on the present requirement and the future expansion on a 10 to15 year scenario.

(c) Reactive compensation as indicated by system studies shall be provided. The series compensation shall be fixed or variable or a combination of both (partly fixed and partly variable). Similarly shunt compensation shall be either switched or non-switched type.

(d) The selection of switching schemes shall be based upon requirements for operational flexibility, system safety, reliability, availability and cost.

(2) **Air Insulated sub-stations (AIS)**

(a) The switching schemes as per Table: III- 3 shall generally be adopted at different voltage levels in AIS depending on the importance of the installation.

Table: III- 3

Main and transfer bus or double bus scheme	66 kV & 132kV
Double main and transfer bus scheme or double bus scheme	220kV
Breaker and a half scheme or double main and transfer bus scheme	400 kV
Breaker and a half scheme or double bus and double breaker scheme	765 kV

(b) In case of AIS, bus-bars shall be either of the rigid type with tubular aluminium bus conductor or flexible stranded conductor with ACSR or AAAC or other suitable conductors. The conductor of appropriate rating and the number of conductors to be used in case of bundle conductors shall be selected considering power flow requirements and ambient conditions. For the rigid bus-bar arrangement, aluminium pipes conforming to relevant standard shall be used.

(c) Outdoor Air Insulated Sub-station or switchyard shall be shielded against direct lightning stroke by provision of overhead shield wire or earthwire or spikes (masts) or a combination thereof.

(3) **Gas insulated sub- stations**

(a) Gas Insulated Sub- station (GIS) installations shall generally be preferred to conventional AIS as a techno-economic solution for locations where space is a major constraint and also for seismic prone areas and coastal areas. However, techno-economic analysis shall be done to determine the preference for each GIS installation. The GIS shall comply with relevant standards. The GIS installations shall be outdoor or indoor type.

(b) The switching scheme has a large impact on the total cost of the GIS and shall be properly evaluated for a particular project. Generally, single bus with or without sectionalization and double main bus switching schemes shall be used depending on the voltage level and the importance of the installation. However, other types of switching schemes can also be considered based on techno-economic analysis.

(c) GIS shall be isolated phase or three phase non-magnetic enclosure type for voltage less than 400kV. For 400kV and higher voltage levels, it shall be isolated phase enclosure type.

(d) The arrangement of gas sections or compartments shall be such as to facilitate future extension on either end without any drilling, cutting or welding on existing equipment from any manufacturer and without the necessity of moving or dislocating the existing switchgear bays.

(e) The design shall be such that all parts subjected to wear and tear are easily accessible for maintenance purposes. The equipment shall be protected against all types of voltage surges and shall necessarily include any component or assembly required for this purpose.

(4) The grounding system shall be designed for expected life of the sub- station for rated fault current as indicated in Table: III- 1 under clause 45. Earthing system for the entire switchyard, equipment and buildings shall be provided in accordance with relevant IS /IEEE standards. The touch and step potential limits shall be maintained within acceptable limits as per relevant standards.

(5) The switchyard or sub-station layout shall be decided with due consideration to statutory safety requirements, ease of erection and maintenance etc. Safety clearances shall be maintained in accordance with the Central Electricity Authority (Measures relating to Safety and Electricity Supply) Regulations as and when these are notified by the Authority. The clearances shall be adequate for moving portable equipment for maintenance and maneuvering personnel for carrying out maintenance. Clearances from adjacent live parts shall be maintained for safety.

47. Salient Technical Particulars and Requirements of Sub-stations and Switchyards

(1) **System design parameters**

(a) The system design parameters of sub-stations and switchyards shall be as given below in Table: III-4.

Table: III- 4

Sl. No.	Parameter	66 kV	132 kV	220 kV	400 kV	765 kV
1.	Highest system voltage (kV)	72.5	145	245	420	800
2.	Rated frequency	50 Hz	50 Hz	50 Hz	50 Hz	50 Hz
3.	No. of phases	3	3	3	3	3
4.	Rated insulation levels					
(i)	Full wave impulse withstand voltage (1.2/50 micro sec.) (kVp)	325	650	1050*	1425*	2100*
(ii)	Switching impulse withstand voltage (250/2500 micro sec.) dry & wet (kVp)	-	-	-	1050	1550
(iii)	One minute power frequency withstand voltage dry (kVrms)	140	275	460	630	830
5.	Minimum corona extinction voltage (kVrms phase to earth)	-	105	156	320	508
6.	System neutral earthing	Effectively earthed				

* for windings of transformers and reactors refer Table: III- 5.

The above parameters are for installations at altitudes upto 1000m above Mean Sea Level (MSL). For higher altitudes, Insulation level requirements shall be kept higher as per relevant standards.

(b) The insulation level for the transformer and reactor windings and bushings shall be as per Table: III- 5.

Table: III- 5

	WINDING			BUSHING		
Rated voltage	Rated power freq. withstand voltage (kVrms)	Rated switching impulse withstand voltage (kVp)	Rated lightning impulse withstand voltage (kVp)	Rated power freq. withstand voltage (kVrms)	Rated switching impulse withstand voltage (kVp)	Rated lightning impulse withstand voltage (kVp)
800kV	-	1550	1950	830	1550	2100
420kV	-	1050	1300	630	1050	1425
245kV	395	-	950	460	-	1050
145kV	275	-	650	275	-	650
72.5kV	140		325	140		325
52kV	95	-	250	95	-	250
36kV	70	-	170	70	-	170
24 kV	50	-	125	50	-	125
17.5kV	38	-	95	38	-	95
12 kV	28	-	75	28	-	75

(2) **Main equipment**

(a) Power Transformers

(i) The transformers shall comply with relevant standards in general. The transformers shall be of two winding type or auto-transformers. The transformers above 100 MVA rating shall be provided with tertiary winding. The transformer shall be provided with On Load Tap changer (OLTC) as per power system requirement.

(ii) At existing sub-stations, the impedance, vector groups, OLTC connection and range etc. of a new transformer shall be matched with that of the existing transformer(s). Interconnecting transformers provided with suitable OLTCs shall be suitable for bi-directional flow of power. Noise level of transformer, when energized at normal voltage and frequency with fans and pumps running and measured under standard condition shall not exceed the values specified in NEMA standard.

(iii) In order to reduce the risk of spreading fire, transformers shall be provided with ‘Transformer Oil Soak Pits’ filled with suitable size of gravels or pebbles below each transformer with voids of capacity adequate to contain the total quantity of oil in the transformer. Alternatively, common ’Burnt oil pit’ of adequate capacity (at least equal to oil quantity in the largest size transformer) may be provided for a group of transformers, connected to all the Soak pits of transformers with adequate size of pipes for fast draining of oil or water from Soak Pits to the Burnt Oil Pit. Every Soak Pit below a Transformer shall be suitably designed to contain oil dropping from any part of the transformer. The Burnt Oil Pit, when provided, shall also be provided with suitable automatic pumping facility, to always keep the Pit empty and available for an emergency.

(iv) Separation walls shall be provided in-between the transformers and also between transformer and reactors as per BIS guidelines.

(v) The transformers may be single phase or three-phase type depending upon transportation constraints. In case single phase transformers are provided, then one single phase unit also shall be kept at site as spare for the entire sub-station or switchyard, in charged condition, so that it can replace any of the units, whenever required.

(vi) Short circuit withstand test shall be conducted on one of each type and rating of transformers to validate the design and quality unless such test has been conducted within last five years on transformer of same design. In case there is change in design before five years, the new transformer design shall be validated by carrying out short circuit withstand test.

(b) *Shunt Reactors*

Shunt reactors, wherever provided, shall comply with relevant standards in general. Shunt reactors upto 420 kV rated voltage shall have linear voltage vs. current (V/I) characteristics upto 1.5 per unit voltage. 800 kV Shunt reactors shall have linear V/I characteristics upto 1.25 per unit voltage. If required, the neutral of the line reactors shall be grounded through adequately rated neutral grounding reactors to facilitate single phase auto-reclosure. The neutral of shunt reactors shall be insulated to 550 kV peak for lightning impulse and shall be protected by means of 145 kV class surge arresters in case of line reactors of 420kV or 800kV rated voltage.

(c) *Circuit Breakers*

(i) Circuit breakers shall comply with relevant standards. The interrupting medium of circuit breakers shall be SF_6. Circuit breakers of 220kV and above voltage class shall be suitable for single phase and three phase auto-reclosing. Circuit breakers of 132kV and below voltage class shall be suitable for three-phase auto-reclosing. Each circuit breaker of 132kV and above rating shall be provided with 2 nos. of trip coils. Two sets of trip circuits shall be connected to separate fuse or MCB controlled DC supplies for greater reliability. The circuit breaker shall have the provision for local manual trip which shall be at a position easily accessible to the operating person. Maximum rated break time for circuit breakers shall be as given below:

765 kV	-	40ms
400 kV	-	40ms
220 kV	-	60ms
132 kV	-	100ms
66 kV	-	100ms

(ii) In accordance with the power system requirement, the circuit breakers of 400kV and above class shall be provided with Pre-insertion resistors (PIR) for controlling switching over voltage on lines of length more than 200km.

(d) *Disconnectors and Earthing Switches*

The disconnectors and earthing switches shall comply with relevant standards. Earthing switches shall be provided at appropriate locations to facilitate earthing of outgoing transmission lines to enable maintenance. Main blades and earth blades shall be interlocked with both electrical and mechanical means, which shall be fail-safe. Earthing switches for 132kV and higher voltages shall be suitable for induced current switching duty as per relevant standard. Earthing switches shall be suitable for electrical and manual operation. Only local operation is recommended for earth switches. High speed earth switches for GIS installation shall have rated fault making capability. In case of GIS installations, high speed earthing switches shall be provided for grounding purpose at over head line terminations and also for cable terminations where cable length is long. Disconnectors for 220 kV and higher rating shall have provision for remote and manual operation. Disconnectors for 132kV and lower rating shall have provision for manual operation and may have provision for remote operation as per requirement.

(e) *Current Transformers*

Current transformers shall comply with the relevant standards. The rated currents and ratio, the number of secondary cores (protection or metering), accuracy class, burden, secondary winding resistance, knee point voltage and excitation current shall be in accordance with the requirements of the protection system. The accuracy class for metering core shall be equal to or better than the accuracy class of the meter specified in the Central Electricity Authority (Installation and operation of Meters) Regulations, 2006. Digital optical current transformers shall also be acceptable in place of conventional current transformers.

(f) *Voltage Transformers*

Voltage transformers shall comply with the relevant standards. The number of secondary cores (protection or metering), accuracy class and burden shall be in accordance with the requirements of the protection system. The accuracy class for metering core shall be equal to or better than the accuracy class of the meter specified in the Central Electricity Authority (Installation and operation of Meters) Regulations, 2006. Voltage transformers can be either electromagnetic type or capacitive type. Wherever PLCC is required, capacitor type voltage transformers (CVT) complying with relevant standards shall be used as the same are suitable for carrier coupling. The capacitance of CVT shall be decided depending on PLCC requirements. Digital optical voltage transformers shall also be acceptable in place of conventional voltage transformers. In case of GIS installations, SF_6 filled voltage transformers shall be electromagnetic type.

(g) *Surge Arresters*

Station class, heavy duty, gapless metal oxide (ZnO) type surge arresters conforming to relevant standards in general shall be provided. The rated voltage, Continuous Operating Voltage (COV), energy handling capability, nominal discharge current and other characteristics of a surge arrester shall be chosen in accordance with power system requirements. Surge arresters shall be provided at locations decided in accordance with insulation coordination studies. These shall be fitted with pressure relief devices and diverting ports suitable for preventing shattering of porcelain housing providing path for the flow of rated currents in the event of failure of surge arrester. A leakage current monitor with surge counter shall be provided with each surge arrester.

(h) *Line Trap*

A line trap, intended for insertion in a high voltage power transmission line between the point of connection of carrier frequency signals and adjacent power system elements such as bus bars, transformers etc., shall consist of a main coil in the form of an inductor, a tuning device and a protective device. The tuning device shall be so arranged as to permit replacement without removing the line trap. It shall be so designed that neither significant alteration in the line trap blocking requirements nor physical damage shall result from either temperature rise or the magnetic field of the main coil at rated continuous current or rated short time current. The protective device shall be so designed and arranged that neither a significant alteration in its protective function nor physical damage shall result either from temperature rise or the magnetic field of the main coil at rated continuous current or rated short time current.

(i) *Insulators*

The minimum creepage distances shall be decided for the maximum pollution condition in the area of installation, including any transient conditions, causing different pollution levels as per Table: III- 6.

Table: III- 6

Pollution level	**Creepage distance as per relevant Standard** (mm/kV of line-to-line voltage)
Light	16
Medium	20
Heavy	25
Very heavy	31

(3) **Sub- station and switchyard support facilities**

(a) *AC & DC System:*

AC & DC supplies shall be provided as per requirements given in Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007. For computation of capacity of battery in attended sub- station or switchyard, in general, the minimum durations assumed shall be as per Table: III- 7.

Table: III- 7

	Where standby battery is provided	Where standby battery is not provided
Steady and continuous load	3 hours	6 hours
Emergency lighting loads	1 hour	2 hours

AC and DC distribution system shall be so designed as to meet the requirement of the sub- station.

(b) *Fire Detection, Alarm and Protection System for Sub- station and Switchyard*

(i) A comprehensive fire detection, alarm as well as fire protection system shall be installed in conformity with relevant IS. In addition, all buildings shall conform to National Building Code. Fire protection system shall be designed as per the guidelines of Tariff Advisory Committee (TAC) and /or NFPA.

(ii) The transformers or reactors of 10 MVA and higher rating or oil filled transformers or reactors with oil capacity of more than 2000 litres shall be provided with automatic high velocity water spray system as per relevant IS or Nitrogen injection based fire protection system. The transformers or reactors of 220kV or higher voltage may preferably be provided with Nitrogen injection based fire protection system in addition to automatic high velocity water spray system.

(iii) The control room shall be provided with fire detection and alarm system based on smoke detectors and/or heat detectors. The fire alarm system shall conform to relevant standards.

(iv) Water hydrant system shall be provided for the following areas in the sub- stations and switchyards:

- DG set
- Auxiliary power supply system area
- Stores
- Fire fighting pump house
- Transformers or reactors

(v) Portable fire extinguishers shall be provided in the control room building, fire fighting pump house, stores and DG set room.

(vi) In case of switchyard associated with generating stations, water supply system can be extended from the fire water pump house provided for the generating station.

(c) *Lighting*

(i) Adequate indoor and outdoor lighting including street lighting shall be provided for the sub- station and switchyard. Adequate normal and emergency AC & DC lighting shall also be provided in the control room and other identified locations of the sub- station or switchyard. Energy conservation measures and energy efficient lighting devices shall be adopted, while designing the lighting system.

(ii) Average illumination levels shall be maintained as per relevant standard.

(d) *Control Room*

Sub- station or switchyard control room shall be provided to house the control and relay panels, PLCC equipments, telemetry equipments and recording equipments, AC & DC distribution boards, DC batteries etc. Air conditioning shall preferably be provided in the building as a functional requirement. In case of sub-station or switchyard with automation system with distributed architecture, intelligent electronic devices (IEDs) including protective relays, PLCC panels may be provided in air conditioned kiosks located in the switchyard.

(e) *Oil Evacuating, Filtering, Testing & Filling Apparatus*

To monitor the quality of the oil for satisfactory performance of transformers and shunt reactors, and for periodical maintenance, necessary oil evacuating, filtering, testing and filling apparatus shall be provided at a new sub- station or new switchyard or for a cluster of sub-stations and switchyards. Oil tanks of adequate capacities for storage of pure and impure transformer oil shall be provided.

(f) *SF_6 Filling, Evacuation, Filtering, Drying & Recycling Plant*

SF_6 filling, evacuation, filtering, drying and recycling plant with adequate storage capacity shall be provided at a new sub- station or new switchyard or for a cluster of sub-stations and switchyards along with trolley for filling or evacuation of SF_6 circuit breaker or gas insulated switchgear (in case of GIS installation) and to monitor the purity, moisture content, decomposition product etc. of SF_6 gas.

(4) **Protection and control**

(a) *Protective Relaying System*

Adequately sectionalized and graded protective relaying system shall be provided for transmission lines, transformers and bus bars so as to automatically isolate the faulty equipment and, thus, minimize the damage to the equipment in the event of faults and abnormal conditions. All main protection relays shall be of numerical type and communication protocol shall be as per IEC-61850.

(b) *Grouping of Protection*

(i) The protection functions shall be subdivided into two groups each being independent and capable of providing uninterrupted protection even in the event of one of the protection groups failing. Wherever two sets of DC sources are available, the relays shall be electrically and physically segregated into two groups (Gr. A and Gr. B) to obtain redundancy, and to take protection systems out for maintenance while the equipment remains in service. Grouping shall be done to the extent possible in such a way that each group can independently carry out protective functions with near equal redundancy. Interconnection between these two groups shall not generally be attempted. However, if found absolutely necessary such interconnection shall be kept to the bare minimum.

(ii) Even in cases when only one battery source is available, segregation of protection and trip circuits in two groups may be considered by giving DC supplies through separate fuses.

(c) The protection in respect of transmission lines, transformers, reactors, bus bars and other provisions shall be as brought out in Tables: III-8, 9 & 10.

(i) *Transmission line protection*

Table: III- 8

Protection	**765 kV**	**400 kV**	**220 kV**	**132 kV or 66 kV**
Main I- Distance protection	Y	Y	Y	Y
Main II- Distance protection or directional comparison protection or phase segregated line differential protection	Y	Y	Y/N	N
Directional IDMT type E/F relay	Y	Y	'Y' if both Main-I & Main-II are distance protections	N

			otherwise 'N'	
Directional IDMT over current and earth fault back up protection	N	N	'Y' if Main-II is not provided otherwise 'N'	Y
Two stage over voltage protection	Y	Y	N	N
Auto reclosing	Y (Single phase and three phase)	Y (Single phase and three phase)	Y (Single phase and three phase)	Y (Three phase)

Transmission lines with distance protection shall, in general, have carrier aided inter-tripping or blocking feature. Separate cores of current transformer and voltage transformer shall be used for Main-I and Main-II.

(ii) *Transformer protection*

Table: III- 9

Protection	**765 kV**	**400 kV**	**220 kV or 132 kV**	**66 kV**
Differential protection	Y	Y	Y	Y
Over fluxing protection	Y	Y	Y	N
REF protection	Y	Y	Y	Y
Backup directional O/C and E/F protection (HV and LV side) or Impedance protection	Y	Y	Y	Y
Buchholz, WTI and OTI (for 1 MVA and above), MOG with low oil level alarm, OSR for OLTC, PRD, SA on both primary and secondary sides of transformers located outdoors and connected to over head lines	Y	Y	Y	Y

Tertiary winding protection	Y	Y	Y (above 100MVA rating)	N
Over load alarm	Y	Y	Y	N

(iii) *Reactor protection*

Table: III- 10

Protection	**765 kV**	**400 kV**
Differential protection	Y	Y
REF protection	Y	Y
Reactor backup protection (impedance type or definite time O/C and E/F protection)	Y	Y
Buchholz, WTI, OTI,MOG with low oil level alarm, SA (if required)	Y	Y

Note: (1) Y – Required; N – Not required; Y/N – Optional

(2) WTI: winding temperature indicator, OTI: oil temperature indicator, PRD: pressure relieve device, OSR: oil surge relay, MOG: magnetic oil gauge, SA: surge arrester

(iv) *Bus bar protection and local breaker backup protection (breaker failure protection)*

Bus bar protection and local breaker backup protection shall be provided in 220kV and higher voltage interconnecting sub- stations as well as in all generating station switchyards. The bus bar protection scheme shall have provision for future expansion.

(v) *Disturbance recorders, event loggers and time synchronisation equipment*

Each 765kV, 400 kV and 220 kV line shall be provided with facility for disturbance recording, distance to fault locator and Time Synchronising Equipment (TSE). Event logger either stand alone or as part of sub- station or switchyard automation system shall be provided for each 220kV and higher voltage class sub- station or switchyard. TSE complete with antenna, all cables, processing equipment etc., shall be provided to receive synchronizing pulse through GPS compatible for synchronization of event logger, disturbance recorder and SCADA/automation system of the sub-station or switchyard.

(vi) *Power line carrier communication (PLCC)*

Power line carrier communication (PLCC) equipment complete for speech transmission, line protection, and data channels shall be provided on each transmission line of voltage rating 132kV and higher. The protection system for 400kV and higher voltage transmission line and the line compensating equipment shall have one hundred percent back up communication channels. Each 765kV or 400kV or 220kV line shall be provided with two protection channels in addition to one speech plus data channel for each direction. In case of 220kV or 132kV lines, the speech and data channel can also be used for protection wherever possible. The generating company and the transmission licensee shall coordinate with each other and ensure the compatibility of PLCC equipment at their respective ends. Optionally, the above functionality may be achieved using wide band communication based on optical ground wire (OPGW) or any other technology.

(vii) *Control concept*

All the breakers in sub- stations and switching stations shall be controlled and synchronized from the switchyard control room or control room of the generating station. Disconnectors of 220kV and higher rating shall have control from remote as well as local whereas the earth switches shall have local control only. Disconnectors and associated earth switches shall be provided with electrical as well as constructional mechanical interlocks. Provision for operation of circuit breakers and disconnectors from remote control stations may also be provided wherever required.

(5) **Cables and cabling**

Cables shall be flame retardant, low smoke (FRLS) type. For laying of cables a broad based system involving cable galleries, trenches, cable racks, shafts etc. shall be provided. In outdoor switchyards, a cable trench system shall be provided. The main considerations and practices shall be:

- A comprehensive philosophy of segregation and proper spacing shall be maintained - control and power cables shall be laid in separate trays.

- Proper attention shall be given to ventilation and heat dissipation aspects particularly in case of HV cables.

Vaults and tunnels if employed shall be provided with dewatering facilities. Cables shall be armoured type. Cables shall be derated for the site ambient and ground temperatures, grouping and soil resistivity.

48. Salient Technical Particulars/ Requirements of High Voltage Direct Current (HVDC) Terminals/ Stations

The design parameters given at clause 47 (1) shall be applicable for the AC equipment installed in the HVDC terminal station to be developed for bulk power transfer over long distances or asynchronous connections (back to back) between areas operating with different frequency regimes. The system parameters given for 400 kV or 220 kV or 132 kV AC system shall be applicable for the commutation voltage for both HVDC back to back and HVDC long distance transmission systems.

(1) **System studies**

HVDC control parameters and equipment shall be designed by carrying out the following studies at different stages of the project:

(a) Main circuit parameters
(b) Short circuit studies
(c) Insulation co-ordination and overvoltage protection
(d) AC & DC filter design, rating and performance
(e) Reactive power studies, switching arrangement & logic
(f) Fundamental frequency temporary overvoltage
(g) Transient overvoltage, surge arrester stress
(h) Runback and run up studies
(i) Sub- synchronous resonance (SSR) studies
(j) AC breaker transient recovery voltage (TRV) and rate of rise of recovery voltage (RRRV) studies
(k) Overload study
(l) AC equivalent study
(m) DC switchgear requirements
(n) Load flow, stability, modulation and frequency controller design study
(o) Dynamic over voltage study
(p) Electrical interface study
(q) Reliability & availability study
(r) Audible noise study
(s) Loss calculation
(t) Dynamic Performance Study (DPS)
(u) Operating characteristic study
(v) Design of electrode line and its impact on dc equipment
(w) Application of VAR compensation equipment
(x) Commutation failure & recovery study
(y) Real Time Digital Simulator (RTDS) studies

(z) HVDC control & protection coordination study
(aa) Overall efficiency study
(bb) AC/DC system interaction

(2) **HVDC equipment**

A typical HVDC station shall consist of the following main equipments:

(a) Thyristor valves and its accessories e.g. damping and grading circuits, converter cooling system, etc.
(b) Converter transformers
(c) AC harmonic filters
(d) Smoothing reactors
(e) DC filters*
(f) AC filters
(g) Control & protection of AC and DC side
(h) Electrical & mechanical auxiliaries
(i) Earth electrode station*
(j) AC switchyard equipment
(k) DC switchyard equipment*
(l) Surge arresters
(m) Measuring instruments

* Not applicable for back to back schemes.

(3) **Converter station AC yard**

(a) *AC Commutating Bus Equipment*

The 400 kV AC circuit breakers, disconnectors, instrument transformers and other switchyard equipment shall be similar to that of the 400 kV equipment specified under clause 47. Continuous current carrying capacity of 400 kV switchgear shall be 3150 Amp and for filter sub-banks, the corresponding rating shall be 2000 Amp. The bus rating shall be adopted according to the calculation considering single bus operation. The switching duties of the AC circuit breakers will be decided based on transient over voltage study, insulation co-ordination, AC filters and protection studies.

(b) *Dynamic Over Voltage Limiter Devices*

Converters connected to relatively weak AC systems may cause dynamic over voltages (DOVs) during load rejection. The DOV limiter shall consist of parallel arrester elements connected phase to phase or phase to ground and designed to absorb the desired amount of energy during a system disturbance. The DOV limiter shall be coordinated with recovery of DC system following a disturbance. The requirements of surge arresters shall be based on the insulation co-ordination study in line with relevant standards. The arresters used shall be metal oxide (ZnO) type conforming to relevant standard.

(c) *AC Harmonic Filters and Shunt Compensation*

(i) The HVDC converter generates harmonics during the conversion process and AC harmonic filters shall be used to limit ac voltage distortion due to harmonics to acceptable levels and also to meet the reactive power exchange requirements based on the studies carried out.

(ii) The AC harmonic filters shall be switched in and out by circuit breakers. Based on the studies, the reactive power requirement for the terminal and bank or sub-bank size shall be determined such that reactive power exchange with the AC bus shall remain within specified limits. Suitable redundancy shall be provided in the sub-bank filters to avoid reduction of transmission capacity of the station due to outage of any particular sub-bank for maintenance.

(iii) The main filter equipments namely capacitors, reactors and resistors shall comply with the requirements of IEC or Cigre standards as follows:

Capacitors	:	IEC 60871-3
Reactors	:	IEC 60289
Resistors	:	Cigre WG 1430 1999

(iv) *Dynamic compensation*: If required, dynamic compensation in the form of STATCOM, SVC, Thyristor Controlled Series Capacitor (TCSC) etc. may be used to improve stability during AC system transient faults. The requirement of dynamic compensation and the rating shall be derived from the studies.

(v) *Shunt Reactor Banks*: Shunt reactors of suitable size shall be provided to meet reactive power exchange requirements derived from the studies. The shunt reactor shall be oil filled and can be switched in or out by a circuit breaker. The shunt reactor shall conform to relevant standard. The shunt reactor shall be covered under automatic switching under the reactive power control strategy.

(d) *Power Line Carrier (PLC) Filtering*

PLC filters shall be installed close to converter transformers to mitigate high frequency harmonic currents generated during thyristor switching.

(e) *Converter Transformers*

(i) The converter transformers shall be single phase two winding or three winding units which shall be decided by size and transportation limitations. The transformers shall comply with the requirements of relevant standards. The maximum flux density in any part of the core and yoke at the rated MVA, voltage and frequency shall be such that under 10% continuous over voltage condition it does not exceed 1.9 Tesla. The maximum temperature rises of oil and winding shall be 40^{o}C and 45^{o}C respectively over an ambient temperature of the terminal where the equipment are installed and operated.

(ii) The insulation level for the transformer AC (line side) windings and bushings shall be as given at clause 47 and insulation levels of the valve side windings shall be determined in accordance with studies. The impedance of the transformer shall be determined in accordance with studies and variations in impedance shall be as per requirements of relevant standards.

(iii) Converter transformers shall be equipped with on load tap changer (OLTC) mechanism and metal oxide varistor (MOV) devices shall be provided between tap leads of the OLTC. The OLTC tap steps shall be determined in accordance with the operating strategy of both the converters.

(iv) The requirements of soak pits and firewalls shall be in line with clause 47.

(f) *Thyristor Valves*

(i) The thyristor valves, used for converting AC to DC or vice versa, shall be complete with associated auxiliaries and cooling system. A twelve pulse scheme shall be used and each twelve pulse thyristor valve shall comprise of several thyristor valve modules in series. Each module shall consist of thyristor, electronic firing system complete with individual thyristor over voltage and over current protection, break over diode firing/protective firing, thyristor control, protection, monitoring and damping, auxiliary power, valve reactors and voltage grading circuit. The thyristor valve assembly shall be tested as per relevant standards.

(ii) The thyristor valves shall be water cooled, air insulated and indoor type. The valves may be either suspended type or floor mounted type depending upon the operating DC voltage and seismic requirements.

(iii) The thyristor valve cooling system shall use de-ionized water circulated in a closed cycle. The cooling unit shall comprise of a de-ionizer, expansion vessel, conductivity, flow and temperature sensors, mechanical filters, etc. Adequate redundancies shall be provided. Necessary control and monitoring including tripping of the HVDC system in case of cooling system failure shall be provided.

(iv) The valves shall be placed in the valve hall which shall have a pressure of 7 mm of water column over atmospheric pressure. The pressurization will be with clean dry air. The valve hall shall have fire & early smoke detection system.

(4) **Converter station DC yard**

(a) The DC yard comprises equipment such as HVDC bushings, smoothing reactors, DC filters, DC current and voltage measuring instruments and switchgear.

(b) The creepage distance for DC yard and other areas shall be maintained as indicated in Table: III- 11 below:

Table: III- 11

Insulator type	**Under light pollution**	**Under heavy pollution**
Indoor Porcelain or Composite for Valve Hall and indoor smoothing reactor area	20 mm/KV	20 mm/KV
Indoor DC yard (other than smoothing reactor)	NA	43 mm/KV
Outdoor Porcelain Insulators or Bushings	50 mm/kV	60 mm/kV
Outdoor Composite Insulators or Bushings	50 mm/kV	50 mm/kV

(c) *DC Wall Bushing*

DC wall bushings, used for electrical connection between the equipment inside the valve hall and the outdoor DC yard shall be of polymer housing as per relevant standards.

(d) *Smoothing Reactor*

The smoothing reactor shall be of oil filled or air core type depending upon techno-economic considerations. The reactors shall generally comply with relevant standards and shall also have been subjected to DC tests as per their application.

(e) *DC Voltage and Current Measuring Devices*

The DC voltage measuring equipment shall be installed at each pole. The DC measuring equipment at pole and neutral bus shall be suitably located based on the control philosophy and different protection zones such that complete pole and neutral equipment are protected.

(f) *DC Filters*

DC harmonic filters shall be provided in DC yard to limit harmonic voltages present on the DC lines (pole lines and electrode lines).

(5) **Control and protection**

(a) Control :

i) DC converter terminals shall be either manned by operator or controlled by remote operation of SCADA system. The control system hierarchy shall be as follows :

- Bipole Control
- Pole Control
- Converter control
- Valve control

ii) The HVDC Bipole shall have control features including but not limited to the following:

- Reactive power controller
- Current and power controller
- Frequency controller

- Power modulator, pole power compensation
- Sub synchronous resonance damping controller
- Load frequency controller (LFC)
- Current margin controller
- Excessive reactive power consumption controller
- AC system stability function, such as power swing damping function

iii) The pole control, converter control, and valve control modules shall also be provided.

(b) Protection :

i) HVDC system protection shall consist of two parts:

- AC side protection
- DC side protection

AC side protection function shall cover the zone for converter transformer, AC filters, shunt capacitors, shunt reactors, and busbars. These protections shall generally follow the same philosophy as in a typical substation i.e. detection of fault by relay and tripping of circuit breaker.

DC side protection covers the zones consisting of the valve hall, DC switchyard including smoothing reactor and DC filters, DC line, electrode line and ground electrode. The protection equipment shall be designed to be fail safe and shall ensure high security to avoid mal-operation/ unwanted shutdown due to protection equipment failures.

ii) Each protection system shall have two identical independent electrical and mechanical systems with following protections.

- Converter differential protection
- DC over current protection
- DC differential protection
- AC conductor ground fault protection
- Commutation failure protection
- DC filter protection (not applicable for back to back schemes)
- DC smoothing reactor protection
- DC line ground fault protection
- DC line Differential Protection
- DC under voltage / over voltage protection

(c) Software based controls and protection shall be used to permit flexibility in effecting modifications at a later date. Protection and controls shall be duplicated for reliability. Protection shall be provided by numerical relays to suit the requirements of reliability and fast controllability of the HVDC system. Operation of the HVDC bipole system shall be possible in the following modes:

(i) Balanced bipolar operation
(ii) Monopolar operation with metallic return
(iii) Monopolar operation with ground operation
(iv) Reduced voltage operation
(v) Power reversal mode

(d) The ‘Sequence of events’ recorder, transient fault recorder, on-line DC Line fault locator, GPS system, visual display system, operator control protection and monitoring system shall be a part of the HVDC system.

(6) **Telecommunication**

For smooth operation of the HVDC system, communication network with high reliability and availability shall be provided for transmission of control and protection signals between the two HVDC terminals. The communication system shall be through optical fibers, PLCC or both.

(7) **Electrode**

(a) The earth electrode station shall be connected to the terminal by means of an overhead transmission line. The earth electrode shall be located approximately 25 km (radial distance) away from the converter station.

It shall be designed to operate continuously at nominal load and overload as per the requirement.

(b) The earth electrode station shall have sub-electrodes. The maximum current density at the sub-electrode surface, i.e. the boundary between backfill (coke) and soil shall not exceed 0.5 A/m^2 in clay soils. The number of sub-electrodes shall be determined considering that 30% of the sub-electrodes are not available.

The amp hour rating for earth electrode shall be selected based on the study for duration of earth electrode current and the service life of the earth electrode station.

(c) Each ground electrode shall have a resistance of less than or equal to 0.3 ohm (both working as an anode and cathode) at 50^0 C ambient temperature.

(d) Touch Voltage (V_t): The touch voltage between any grounded metallic object in the electrode station (including the connection to the overhead electrode line) and any point in the soil which can be touched by a person simultaneously shall not exceed 40 V when the electrode is operating at the 5 sec overload rating.

(e) Step Voltage (V_s):The step voltage at ground level above the ground electrode when the electrode is operating at the Temporary Overload rating shall not exceed (Vs) = 5.0 + 0.03ρs, where ρs is the minimum local soil surface resistivity in ohm-m.

The above values of resistance, touch and step voltages would depend on the actual geophysical characteristics of the soil at the place where the electrode station is located. Suitable mitigation measures may have to be adopted in case the site has high resistivity.

49. Electrical and Mechanical Auxiliaries

The auxiliary power requirement shall be met through two independent feeders. The loads shall be fed through a 415V distribution board using auxiliary transformers. One DG set with auto start facility shall be provided as emergency backup. For HVDC system, one DG set with auto start facility shall be provided per pole as emergency backup. Batteries and battery chargers shall be provided for auxiliaries, DC power supplies, valve hall ventilation systems, etc.. Other electrical auxiliaries provided shall include illumination, public address and communication system, UPS etc. The mechanical auxiliaries shall include air conditioning, ventilation systems**,** fire fighting including VESDA system for valve hall, water supplies, etc.

All auxiliaries shall give full output at voltage variation of ±10% and frequency variation of -5% to +3%.

50. Condition Monitoring of Sub- station and Switchyard Equipment

Diagnostic equipment shall be provided to assess the health of various equipment in substations and switchyards of 132kV and higher voltages. On-line diagnostic equipment shall be dedicated type for those critical equipment the health of which is to be monitored continuously. Portable type on-line diagnostic equipment and off-line diagnostic equipment shall be provided for one or a cluster of substations or switchyards, depending upon the size of the substations or switchyards. The diagnostic equipment shall include dissolved gas analyzer, winding resistance meter, and frequency response analyzer for transformers and reactors, capacitance and tan-delta measuring units for transformers, reactors and instrument transformers, circuit breaker analyser including dynamic contact resistance meter, and leakage current monitor for surge arrester, and relay testing kit. Other necessary diagnostic equipment may be provided at the discretion of the Owner.

PART – B: SUB- STATIONS (33/11 kV, 33/22kV AND 22/11kV)

51. System Parameters

The system should conform to the following design parameters:

Table: III - 12

Parameter	unit	33 kV	22 kV	11kV
Nominal system voltage	kV	33	22	11
Highest system voltage	kV	36	24	12
System earthing		Solidly earthed system	Solidly earthed system	Solidly earthed system
Frequency	Hz	50	50	50
Lightning impulse withstand voltage	kV (peak)	170	125	75
Power frequency withstand voltage (dry)	kV (rms)	75	50	28

52. General Consideration for 33/11 kV, 33/22 kV and 22/11 kV Sub-stations and Switching Stations

(1) The sub-station shall be designed and constructed complying with the requirements mentioned in these standards, applicable Indian Standards (IS) as well as other rules and regulations as per latest amendments. The design and construction of the sub-stations shall be such that they perform their intended functions. In case of conflict the more stringent provisions shall prevail.

(2) The sub-station shall be indoor/ outdoor or underground type depending upon the site requirement. The sub-station shall be either air insulated (AIS) or gas insulated (GIS), as the case may be.

(3) The sub-stations in urban areas shall be provided with Supervisory Control and Data Acquisition (SCADA) System for monitoring and control.

(4) The 33/11 kV or 33/22 kV or 22/11 kV sub-stations shall, at least have adequate capacity to cater to load growth for five (5) years. Adequate land for possible future expansion shall be provided in each case.

(5) The maximum capacity of 33/11 kV or 33/22 kV or 22/11 kV sub-station shall be 60 MVA, 40 MVA and 40 MVA respectively.

(6) Each 33/11 kV or 33/22 kV or 22/11 kV sub-station shall normally have two or more transformers. Each 33/11 kV or 33/22 kV or 22/11 kV sub-station shall have at least two incoming feeders preferably from two different sources.

(7) In case both (the 33 kV or 22 kV) incoming feeders to the sub-station are from the same source (sub-station), each feeder shall supply independent sections of the 33/11 kV or 33/22 kV or 22/11 kV sub-station, the two sections being isolated from each other by bus sectionalizer or isolators.

(8) All sub-stations shall have independent circuit breaker control of 33 kV or 22 kV incoming feeders, transformers and 22 kV or 11 kV outgoing feeders.

(9) All the incoming feeders feeding the sub-stations shall have independent circuit breaker at source end.

53. Selection of Site

(1) The selection of site for 33/11 kV or 33/22 kV or 22/11 kV sub-station shall be made after taking into consideration the capacity and location of the feeding grid sub-station, load in the area, spatial load forecast, demographic factors, the existing network configuration, etc. and the economic, and environmental considerations.

(2) The selection of the site of the sub-station shall be done on the basis of the following:

(a) The site shall be near the load center.

(b) The site shall be such that it is convenient for terminating EHV/HV lines/cables.

(c) The site shall not be in a low-lying area to avoid flooding during the rains.

(d) The site shall be easily approachable in all the seasons.

(e) The site for air-insulated sub-station shall be away from garbage dumping ground to avoid vulture faults.

(f) The land shall be reasonably levelled and shall not have any open drain/ nallah or road crossing it.

54. Sub-station Layout

The layout of the Sub-station shall be such that:

(1) The incoming and outgoing feeders are easily taken to and from the sub-station structures.

(2) Equipment maintenance shall be possible without interrupting the entire supply.

(3) The layout shall be economical and shall not hinder future expansion.

55. Switching Arrangements

(1) Switching arrangements shall ensure operational flexibility, system safety and reliability.

(2) Single bus, single bus with bus sectionalizer, main and transfer bus, double bus or mesh arrangement shall be adopted as per requirement.

56. System Configuration

The system configuration shall be radial, ring or combination of both as per requirements. The radial configuration shall be minimized to improve reliability. In densely loaded city centers, and for essential services and installations, the system shall be of ring configuration.

57. Sub-Station Construction and Main Equipment Selection

(1) The control room building can be single storey or double storey or underground depending upon availability of space.

(2) Concrete padding of appropriate thickness depending upon the weight of the structures shall be provided in the switchyard.

(3) While selecting equipment for the sub-station, de-rating due to increase in altitude and for cables due to depth of burial in the ground shall be given due consideration as per the altitude/depth of burial at the site.

58. Power Transformers

(1) The transformers and fittings and accessories shall comply with the relevant IS.

(2) The 33/11 kV or 33/22 kV or 22/11 kV transformers shall have delta star or delta-zigzag winding connection. At existing sub-stations, the percentage impedance, vector groups, on load tap changer connection and range etc. of the new transformer shall match with that of the existing transformer.

(3) The preferred ratings for 33/11 kV or 33/22 kV or 22/11 kV transformers shall be 6.3, 8, 10, 16 and 20 MVA for urban areas and 1, 1.6, 3.15, 5 and 6.3 MVA for rural areas.

(4) The transformers shall be three-phase type.

(5) The transformer can be oil filled, gas filled epoxy cast dry type or ventilated dry type depending on whether it is installed indoor or outdoor. Outdoor dry-type transformer may be non-ventilated type.

(6) Transformers shall withstand, without injurious heating, combined voltage and frequency fluctuations which produce the over fluxing conditions as: 125% for 1 minute and 140% for 5 seconds.

(7) The maximum temperature rise of oil and winding shall be 35^oC and 40^oC respectively over an ambient temperature of $50\,^oC$.

(8) Each transformer shall be provided with gas and oil actuated Buccholtz relay fitted with alarm (local and remote) and trip contacts, if applicable.

(9) A transformer with off-circuit tap changer shall have taps ranging from (+) 2.5% to (-) 10% in steps of 2.5% each on the higher voltage winding for variation in the voltage. The tap changing switch shall be located in a convenient position so that it can be operated from ground level. The switch handle will be provided with a locking arrangement along-with tap position indication, for locking the switch.

(10) On load tap changing device shall be provided with transformers of 3.15 MVA and higher rating for better voltage control by manual and automatic means.

(11) A transformer with on-load tap changer shall have taps ranging from (+) 5% to (-) 15% in steps of 2.5% each on 33 kV or 22 kV winding for voltage variation.

(12) Assembly of fittings and accessories shall be carried out as per the manufacturers' instructions.

(13) Adequate electrical clearances shall be provided from various live points on the transformer to earthed parts.

(14) Transformers shall be separated from one another and from all walls and partitions to permit free circulation of air complying with requirements of relevant IS.

(15) 33 kV voltage rating transformers shall be separated from one another by a fire wall.

(16) Space shall be provided in front and rear sides of the transformer conforming to Central Electricity Authority (Measures relating to Safety and Electricity Supply) Regulations as and when these are notified by the Authority.

(17) For indoor installation, the room shall be well ventilated for escape of heated air. Air inlets shall be provided near the floor and outlets near the ceiling.

(18) A transformer shall be physically checked and tested for its electrical and mechanical performance characteristics before commissioning.

(19) A transformer shall be provided with two separate body earthing terminals which in turn shall be connected to two separate earth points, besides neutral earthing terminal.

59. Bus-bars

(1) Bus-bars shall be of Rigid type or Strain type.

(2) A bus-bar shall be able to carry the expected maximum load current continuously without exceeding the temperature rise limit as per relevant IS. The capacity of a bus-bar shall also be checked for maximum temperature rise of the conductor under short circuit conditions.

(3) The bus-bar connections and insulator supports shall be mechanically strong and bus-bars shall be supported so as to withstand the stresses generated by vibrations and short circuits.

(4) Aluminium used for the tubes of rigid type bus-bars shall conform to relevant IS.

60. Structures

(1) Structures shall be provided for:

(a) Incoming and outgoing gantries and/or cable supports and terminations.

(b) Circuit breakers, isolators, fuses, insulators, CTs and PTs.

(c) Bus-bar/insulators.

(2) Switchyard structures to support buses, electrical equipment and termination of line conductors shall be made of fabricated steel, Reinforced Cement Concrete (RCC) or Pre-stressed Concrete (PSC), Rail or Rolled Steel Joist (RSJ) depending on technical and economic considerations.

(3) The structures shall be able to withstand tension of conductors and load of the equipment and accessories without guys or stays.

(4) The steel structures shall normally be hot dip galvanised or painted. In highly polluted and corrosive atmospheric conditions galvanised structures with paint shall be used.

(5) Adequate muffing above the ground level shall be provided to avoid water accumulation near the structures.

61. Insulators

(1) Adequate insulation is of prime importance for ensuring reliability of supply, safety of personnel and equipment, etc. The station design shall be such that number of insulators is minimum but at the same time reliability of supply is ensured.

(2) The insulators shall be porcelain or polymer type.

(3) Suitable means shall be provided to accommodate conductor expansion and contraction and there shall not be any undue stress on any part or equipment due to temperature change.

(4) The minimum creepage distances for different pollution levels shall be as per Table: III-6 at Clause 47.

62. Post Insulators

(1) The post insulators shall be of pedestal type and shall conform to relevant IS.

(2) In the areas where problem of insulator pollution is expected (such as near sea or thermal power station, railway station, industrial area, etc.) special insulators viz. semi conducting glazed porcelain or polymer insulators with higher leakage resistance and creepage distance shall be used.

63. Circuit Breakers

(1) Circuit Breakers (CBs) shall comply with the provisions of relevant IS. The circuit breakers shall be SF_6 or vacuum type. Normally vacuum type circuit breakers shall be used for voltage levels of 33 kV and below. The rated voltage for the circuit breakers shall be 36 kV, 24kV and 12 kV for 33 kV, 22kV and 11 kV systems respectively.

(2) Rated short time current rating of 33 kV CBs shall not be less than 25 kA for 1 second and for 22 kV or 11 kV CBs shall not be less than 16 kA for 1 second. In case of rural areas for 11 kV CBs, this shall not be less than 12.5 kA for 1 second.

(3) The operating mechanism shall be motor operated spring charged type, anti pumping and trip free.

(4) The 33 kV, 22kV and 11 kV switchgears can be located outdoor or indoor. The indoor switchgears shall be metal clad, either fixed type or draw out type.

(5) A circuit breaker shall be mounted on individual structure in a fixed position in such a way that adequate sectional clearances are always available from its live parts.

(6) The rated rupturing capacity of the circuit breaker to be installed at any new sub-station shall be at least 25% higher than the calculated maximum fault level at the bus to take care of the increase in short circuit levels as the system grows.

64. 33 kV, 22kV and 11 kV Isolators and Earthing Switches

(1) The isolators shall comply with relevant IS. The rated current shall be at least 630 A at 36 kV and 24 kV. For 11 kV system, isolating switches of 400 Amps at 12 kV shall be used. The isolators shall be gang operated type.

(2) The frame of each isolator switch shall be provided with a separate earthing terminal for each phase for connection to an earthing conductor.

(3) The operating mechanism for the isolators and the controlling circuit breaker shall be interlocked so that the isolators cannot be opened unless the corresponding breakers are in open position.

(4) Earthing switches shall be provided at various locations to facilitate maintenance. Main blades and earth blades shall be interlocked, both electrically and mechanically.

(5) The earthing switch shall be capable of withstanding short circuit current for short duration as applicable to the corresponding isolator. Earthing switches shall be suitable for manual operation.

65. Control and Relay Panels

(1) The control and relay panels shall contain control and metering equipment, relays and annunciation systems for incoming feeders, outgoing feeders, bus bars, switch-gears wherever indoors, instrument transformers and capacitors.

(2) The control and relay panel shall consist of separate cubicle with side covers made of sheet steel and shall be complete with internal wiring, terminals, ferrules and illumination operated with door off and on switch.

(3) The panel shall be suitable for floor mounting and shall be completely dust and vermin proof.

(4) The panel shall be provided with:

(a) Suitable over current and earth fault relays to protect the equipment and system against short circuit current and earth fault current.

The relays shall conform to relevant IS. All relays used shall be suitable for operation with CTs of secondary rated for 1 Amp or 5 Amps.

(b) Measuring instruments such as ammeter, voltmeter and energy meter for 33 kV, 22 kV and 11 kV systems.

(c) Mimic diagrams.

(d) Annunciation, alarms and trip facilities.

(5) Panels shall have degree of protection conforming to relevant IS.

66. 33 kV, 22 kV and 11 kV Lightning Protection

(1) The surge arrester (SA) which responds to over-voltages without any time delay shall be installed for protection of 33 kV switchgear, transformers, associated equipment and 33 kV lines.

(2) Station class, heavy duty, gapless metal oxide (ZnO) type surge arresters in general shall be provided on the buses, high voltage and low voltage sides of

all transformers and on the incoming terminations of 33 kV/22 kV lines. The arresters shall conform to relevant IS.

(3) Surge arresters shall be provided at the junction of overhead line and under ground cable. These shall also be installed on 11 kV overhead lines, both at sending end and terminating end.

(4) The rated voltage, continuous operating voltage, energy handling capability, nominal discharge current and other characteristics of surge arresters shall be chosen in accordance with system requirements.

(5) Surge arresters shall be single-phase units suitable for outdoor duty. These arresters shall draw negligible current at operating voltage and at the same time offer least resistance during the flow of surge current.

(6) The rated voltage of surge arresters shall be 30 kV for use on 33 kV systems and with nominal discharge current rating of 10 kA. For system voltage of 22 kV, the rated voltage shall be 20 kV with nominal discharge current rating of 7.5 kA.

(7) The rated voltage of surge arresters shall be 9 kV (rms) for solidly earthed 11 kV system (co-efficient of earth not exceeding 80 per cent as per relevant IS) with all the transformer neutrals directly earthed. The nominal discharge current rating shall be 5 kA.

(8) Surge arresters for transformers shall be mounted as near the transformers as possible and the star point shall be connected to the independent earthing point.

(9) Surge arresters shall be connected to two independent earthing connections.

(10) The earthing lead for surge arrester shall not pass through any iron or steel pipe, and shall be taken as directly as possible from the surge arrester to a separate earth electrode or junction of the earth mat already provided for the sub-station. Bends shall be avoided.

67. Instrument Transformers (Current and Voltage Transformers)

(1) **Current transformers (CTs)**

(a) Current transformers shall comply with relevant IS.

(b) The rated currents and ratio, the number of secondary cores (protection/metering), accuracy class, burden, secondary winding resistance, knee point voltage, instrument security factor and excitation current shall be as per the requirements of the protection and metering system.

(c) The primary side rating shall depend on the rating of the power transformer of the sub-station. Current transformers with secondary side rating of 1 Amps or 5 Amps shall be provided. Where the distance between the primary equipment and relay panel is large, CT of 1 Amp secondary current may be used to avoid large VA burden on the CT.

(d) The CT may be oil filled or resin type for outdoor use and shall normally be cast resin type for indoor use.

(e) The accuracy class for metering core shall be equal to or better than the accuracy class of the meter specified in the Central Electricity Authority (Installation and Operation of Meters) Regulations, 2006.

(2) **Voltage transformers (VTs)**

(a) Voltage transformers shall conform to relevant IS.

(b) The number of secondary cores (protection/metering), accuracy class and burden shall be as per the requirements of the protection system.

(c) Voltage transformers shall be of electromagnetic type.

(d) The voltage transformers shall be oil filled or cast resin type for outdoor use. The indoor voltage transformers shall normally be cast resin type.

(e) The neutral point of star connected secondary windings of voltage transformers shall be earthed. Multiple earthing of voltage transformers shall be avoided under any circumstances.

(f) The accuracy class for metering core shall be equal to or better than the accuracy class of the meter specified in the Central Electricity Authority (Installation and Operation of Meters) Regulations, 2006.

68. Control Room

(1) Control room shall be provided to house the control and relay panels and all other indoor equipment, and measuring and recording instruments required for control and operation of the sub-station.

(2) Adequate space shall be provided for the operation and maintenance staff.

(3) Provision of space for future expansion shall also be kept.

69. Earthing Arrangement

(1) Earthing shall be provided for:

(a) Safety of personnel.

(b) Preventing and minimizing damage to the equipment as a result of flow of heavy fault currents.

(c) Improving reliability of power supply.

(2) Earthing shall be carried out in accordance with relevant IS and Central Electricity Authority (Measures relating to Safety and Electricity Supply) Regulations as and when these are notified by the Authority.

(3) The step and touch potentials shall be within safe limits.

70. Reactive Power Compensation

(1) Shunt capacitors shall be connected on secondary side of 33/11 kV, 33/22 kV or 22/11kV transformers.

(2) Capacitors and the residual voltage transformer shall be as per relevant IS.

(3) The capacitors shall be of automatic switched type for sub-stations of 5 MVA and higher capacity.

(4) Where un-switched (fixed) capacitors are provided, the rating shall be chosen so as to prevent over compensation during off peak periods.

(5) Each capacitor unit shall be provided with a built-in discharge resistor of adequate rating to discharge the residual voltage as per relevant IS.

(6) The capacitors shall be fixed firmly to the supporting structure to make them immovable.

(7) The capacitors shall be earthed appropriately to avoid accidental leakage of charge.

(8) Where the sub-station is feeding loads which have high harmonic levels, suitable harmonic filters shall be installed.

(9) In cases of sub-stations loaded with highly fluctuating loads like arc furnaces etc., flickers and voltage regulation problems shall be overcome by installation of static var compensators (SVC).

71. Cables

(1) Power and control cables of adequate current carrying capacity and voltage rating shall be provided.

(2) Power cables shall be XLPE insulated, PVC sheathed type conforming to relevant IS. Cables shall be flame retardant low smoke (FRLS) type. Cables shall be de-rated for the site's ambient and ground temperature, grouping and soil resistivity as per IS. Proper attention shall be given to ventilation/heat dissipation aspects particularly in case of HV cables.

(3) The control cables shall be of copper and conform to relevant IS.

(4) Cables shall not be laid directly on the trench floor.

(5) The cables shall be segregated by running in separate trenches or on separate racks, with the highest voltage class cables laid at the highest racks/tiers.

(6) The cable trenches shall be properly sloped so as to drain freely any water which may enter.

(7) Care shall be taken in sub-station design to permit easy entry of cables into switchgear and convenience of handling afterwards.

(8) Segregation of AC and DC control cables and power cables shall be done.

(9) Separate control cables shall be used for each CT and VT.

(10) Sufficient extra length of cable shall be provided for repair of faults in terminations inside the switch gear.

(11) Cable laying shall be done as per manufacturer's recommendation. The relevant drawings of cable sizes, routes and the termination details of control cables in the panels shall be available at work site and shall be preserved for future use and reference in the sub-station.

(12) All cable ends shall be suitably labeled to facilitate easy identification. Ferrules used on ends of control cables shall match with the details shown in the relevant termination drawings.

(13) Adequate number of spare cores shall be included in all control cables.

72. Telecommunication System

(1) The telecommunication system shall be reliable.

(2) A dedicated telecommunication system i.e. radio, mobile telephone, satellite or a combination of these shall be provided, besides usual public communication and local Public Address (PA) system.

(3) The radio communication network shall be in the VHF/UHF frequencies.

73. Automation System

State-of-art systems such as supervisory control and data acquisition system (SCADA) and data acquisition system (DAS) shall preferably be provided in the 33 kV or 22 kV sub-stations, associated feeders and distribution transformers for improving the operational flexibility, minimizing restoration time of power supply and preventing overloading of lines and transformers in real time mode.

74. Sub-station Support Facilities

(1) **DC supply arrangement**

The battery charger, battery and load shall be connected in parallel and work as a system.

(2) **Battery**

(a) The 24V/ 30V/ 48V DC batteries shall be stationary lead acid or nickel cadmium type. The capacity and discharge rate shall be as per the load requirement.

(b) The batteries shall conform to relevant IS.

(3) B**attery charger**

The battery chargers shall be of static type. The battery charger shall be capable of continuous operation at the rated load in float charging mode. The charger in boost charging mode shall be capable of boost charging the associated DC battery at the desired rate.

(4) **Auxiliary power supply transformer**

An auxiliary power supply transformer of adequate capacity connected to the 33 kV or 22 kV or 11 kV bus shall be provided to meet the auxiliary and lighting loads of the sub-station.

(5) **Oil and SF_6 evacuating, filtering, testing and filling apparatus**

Oil and SF_6 filling, evacuation, filtering and testing plants with adequate storage facilities shall be provided for a cluster of sub- stations as per requirement.

75. Fencing and Approach Arrangement

Fencing shall be provided around the sub- station. A metalled approach road to transport the equipment should be provided leading from the main road.

76. Lighting System

Energy efficient lighting system shall be provided at the sub- station. The lighting system shall comprise of the following:

(1) **AC normal lighting**

AC lights shall be connected to AC lighting panels. All the lights connected to the AC lighting system in different areas shall be connected to the main lighting distribution boards (LDBs).

(2) **DC emergency lighting**

Emergency lighting operated on the DC system shall be provided in strategic locations viz. control room, battery room, passages etc.

77. Fire Fighting System

(1) Proper attention shall be given to isolation, limiting and extinguishing of fire so as to prevent damage to costly equipments, reduce chances of serious interruption of power supply and ensure safety of personnel. The layout of the sub- station itself shall be such that the fire shall not spread from one to other equipment and areas as far as possible.

(2) Fire hydrant, carbon dioxide (CO_2) type fire extinguisher or dry chemical powder type fire extinguisher conforming to relevant IS shall be provided as per site requirement.

PART–C: DISTRIBUTION SUB-STATIONS (33/0.4 KV, 22/0.4 KV AND 11/0.4 KV)

78. General

(1) The system shall conform to the following design parameters:

Table: III-13

Parameter	**unit**	**33 kV**	**22 kV**	**11kV**	**0.40 kV**
Nominal system voltage	kV	33	22	11	0.40
Highest system voltage	kV	36	24	12	0.44
System earthing		Solidly earthed system	Solidly earthed system	Solidly earthed system	Solidly earthed system
Frequency	Hz	50	50	50	50
Lightning impulse withstand voltage	kV (peak)	170	125	75	60
Power frequency withstand voltage (dry)	kV (rms)	75	50	28	10

(2) The distribution sub- stations (DSS) shall normally be located near load centre.

(3) The DSS can be indoor or outdoor type. The sub-station can be constructed underground where there is paucity of space or for supply to underground installations. DSS in flood prone areas shall be above the expected water level during flood.

(4) The DSS can also be placed on rooftop. It shall be ensured that the building is suitable for bearing the load of the DSS. Adequate fencing or isolation arrangements shall be ensured. Only dry type transformer shall be used for rooftop and underground installation.

(5) The DSS can be conventional, package type or completely self protected type (CSP).

(6) The capacity of DSS shall be as per the load requirement keeping in view the future load growth for 2 to 3 years.

(7) In the selection of the equipment for the Distribution Sub station derating due to increase in altitude and for cables due to depth of burial shall be given due consideration as per the altitude / depth of burial at the site.

79. Distribution Transformers

(1) The transformer shall conform to relevant IS.

(2) The transformer can be oil filled or dry type depending on requirements. In indoor installations, installations under stilts, rooftop and underground installations the transformer shall be only dry type.

(3) Energy efficient transformers made of high grade cold rolled grain oriented (CRGO) steel or amorphous material shall be used. Transformers made out of scrap CRGO material shall not be used. The efficiency of distribution transformers shall not be less than the percentage values indicated in the table below:

Table: III- 14

Distribution transformer	Efficiency (%) At 50% loading	Efficiency (%) At 100% loading
11 / 0.4 kV (25 kVA and below)	98.0%	97.0%
11 / 0.4 kV (above 25kVA)	98.8%	98.0%
22 / 0.4 kV	98.5%	98.0%
33 / 0.4 kV	98.8%	98.2%

(4) The transformer may be single phase or three phase. The cooling shall be ONAN for oil filled transformers.

(5) The 33/0.4 kV distribution transformers shall normally have standard rating of 100, 160, 200, 315, 400, 500, 630, 1000, 1250, 1600, 2000 or 2500 kVA depending on requirement. Lower ratings can also be used for rural and lightly populated urban areas.

(6) The 22/0.4 kV distribution transformers shall normally have standard rating of 25, 63, 100, 160, 200, 315, 400, 500, 630, 1000, 1250, 1600, 2000 or 2500 kVA depending on requirement. Lower ratings can also be used for rural and lightly populated urban areas.

(7) The 11/0.4 kV distribution transformers shall normally have standard rating of 6.3, 7.5, 10, 16, 25, 63, 100, 160, 200, 250, 315, 400, 500, 630, 1000, 1250, 1600, 2000 and 2500 kVA. Lower ratings can also be used for rural and lightly populated urban areas.

(8) Any standard rating other than the ratings mentioned in sub-clauses (5), (6) and (7) can also be chosen based upon technical and economic considerations.

(9) Lower capacity transformers (100 kVA and less) shall normally be used. The higher capacity (more than 100 kVA) shall be used for concentrated loads or areas with high load density where there are space constraints.

80. Taps

(1) No tapping shall be provided for transformers up to 100 kVA rating.

(2) For ratings above 100 kVA to 200 kVA, tapping may be provided depending upon requirement on the higher voltage winding within range of (+) 5.0% to (-) 7.5% in the steps of 2.5%.

(3) For ratings higher than 200 kVA, tapping shall be provided on the higher voltage winding within range of (+) 5.0% to (-) 15.0% in steps of 2.5%.

(4) Tap changing shall be carried out by means of an externally operated self position switch and when the transformer is in de-energized condition. Each tap change shall result in variation of 2.5% in voltage. Provision shall be made for locking the tapping switch handle in position. Suitable Aluminum anodized plate shall be fixed for tap changing switch to know the position number of the tap.

81. Transformer Mounting Structure

(1) The transformer shall be mounted on a single pole, H pole structure or on a plinth depending upon site requirements, size and weight of the transformer.

(2) Direct single pole mounting shall be used for transformers upto 25 kVA only.

(3) The transformers of more than 25 kVA and upto 250 kVA can be mounted on H pole structure or on plinth. Transformers above 250 kVA shall be mounted on plinth only.

(4) The structures shall be provided with anti-climbing devices and danger board.

(5) The plinth shall be higher than the surroundings. The plinth foundation shall be of concrete.

(6) Plinth mounted distribution sub-stations shall be adequately protected by fencing so as to prevent access to the equipment by unauthorized persons,

animals and shall be provided with standard danger boards. The enclosure shall permit free circulation of air on all sides.

82. Surge Arresters

(1) Surge arresters shall normally be installed on the high voltage side of the transformer connected to overhead lines. Surge arrester shall also be provided on the low voltage side in areas of high isoceraunic activity.

(2) Surge arresters of rating 9 kV on 11 kV, 20 kV on 22 kV and 30 kV on 33 kV outdoor type shall be used for diverting the lightning surges to earth.

83. LT Distribution Box

(1) LT distribution box consisting of breaker and fuse cutouts conforming to relevant IS shall be provided from where distribution feeders shall be taken out.

(2) The size of the box shall be suitable for accommodating moulded case circuit breaker (MCCB), fuse cutouts, cable connectors, bus-bars etc.

(3) The distribution box shall be mounted at a height of 1.5 to 2 metres for pole mounted distribution transformers while the feeder pillar box can be installed at ground level, with adequate clearance.

(4) The capacity of lugs for cables, connecting strips, bus bars shall be as per requirement.

84. Protection System

(1) **33/ 0.4 kV DSS and 22/0.4 kV DSS**

(a) Suitable high rupturing capacity cartridge fuse or moulded case circuit breakers (MCCB) or miniature circuit breakers (MCB) or air circuit break switch (ACB) shall be provided on low voltage side.

(b) The high voltage side of these transformers shall be protected by circuit breakers or drop out fuses.

(2) **11/ 0.4 kV DSS**

(a) Suitable high rupturing capacity cartridge fuses or moulded case circuit breakers (MCCB) or miniature circuit breakers (MCB) or air break switch shall be provided on low voltage side for transformers of 100 kVA and above. The high voltage side of these transformers shall be protected by drop out expulsion type fuses or circuit breakers.

(b) Horn gap fuse with air break switch shall be provided on high voltage side and switch fuse unit or wire fuse on low voltage side shall be provided for transformers below 100 kVA.

85. Earthing

(1) Pipe earthings or rod earthing shall be provided for the distribution sub-station. 3 Nos. earth pits with three grounding electrodes shall be provided. Adequate quantity of charcoal and salt shall be used to keep the earth resistance low.

(2) Earth connections shall be made as under :

(a) To one of the earth electrode:

One direct connection from the high voltage surge arrester and another direct and separate connection from low voltage surge arrester if low voltage surge arrester is provided.

(b) To each of the remaining two electrodes:

(i) Separate connection from the neutral side of the transformer.

(ii) Transformer body earthing 1 No., one connection from the handle of the 33 kV, 22 kV or 11 kV air break switch, and channel earthing.

(iii) One separate connection from the earthing terminal of the poles.

(3) The transformer neutral earth pit shall be independent just opposite the surge arrester earth pit.

86. LT Cables

(1) The XLPE cables shall be used for connecting LT supply from transformer bushings to the LT circuit breaker in the distribution box and for taking out outgoing feeders from the fuse units to the overhead lines. These cables shall be as per relevant IS and IS marked.

(2) The LT cables, other than XLPE, shall also be as per relevant IS and IS marked

(3) The LT cables may be armoured or unarmoured for transformers rated less than 100 kVA and shall be armored for transformers of 100 kVA and higher ratings.

(4) The cables shall be properly clamped to the support without damaging the insulation.

(5) A loop arrangement shall be made at the connecting end and laying of cables shall be in such a way that rain water does not enter.

87. Meters

(1) Meters shall be provided on the distribution transformer (LV side) for energy audit purposes of the corresponding LV network.

(2) The installation of meters shall be in conformance to the Central Electricity Authority (Installation and Operation of Meters) Regulations, 2006.

88. Reactive Compensation

(1) Where the power factor is low, reactive compensation shall be provided on the distribution transformers by fixed or automatic switched type capacitors of adequate rating.

(2) In case of fixed capacitors it shall be ensured that the rating of the capacitors is such as to prevent over compensation during off peak period.

(3) In cases where loads fluctuate very fast, a suitable dynamic compensation like STATCOM/ thyristor switched capacitors shall be considered.

(4) In loads which are rich in harmonics, suitable harmonics filters or de-tuned filter banks shall be considered.

89. Auxiliary Transformer

Auxiliary transformer of suitable rating shall be provided in the sub-station for meeting lighting and other auxiliary loads.

SCHEDULE- IV

TECHNICAL STANDARDS FOR CONSTRUCTION OF ELECTRIC LINES

90. Preliminary

This Schedule stipulates the minimum technical requirements for construction of Electric Lines in the following two parts:

Part - A : Electric Lines (66 kV and above)

Part – B: Electric Lines (33 kV and below**)**

PART- A: ELECTRIC LINES (66 kV AND ABOVE)

91. General

(1) Whenever a new transmission line is planned and constructed, the Owner shall ensure that the proposed new installation is compatible with the existing power system and is suitable for becoming, on commissioning, a natural and integral part of the power system. The overall performance and output as well as detailed operating characteristics and specifications of the installation shall conform to the rest of the power system i.e. the design and construction features shall be compatible with the system to which the new installation will be connected.

(2) The Owner shall ensure tie-up arrangements which are necessitated by the proposed installation and which must be carried out simultaneously by other entities before the new installation is commissioned and connected to the power system. The owner connecting his new installation shall abide by the Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007.

(3) The transmission line shall be designed and constructed to give a life of not less than 35 years.

92. Transmission System

The objective of system planning is to develop a power system with a level of performance characterized by an acceptable degree of adequacy and security. The salient features for the transmission system shall be as summarized below:

(1) The transmission system shall be planned in an integrated manner and optimized considering the total network under CTU and STU.

(2) The adequacy of the transmission system shall be tested for one or more load generation scenarios comprising of peak and off peak conditions in summer, winter and monsoon seasons.

(3) Right of way for transmission lines shall be optimized keeping in view the corridor requirement for the future by adopting suitable alternative of multi-circuit or multi-voltage lines as applicable.

93. Routing of Transmission Line

The transmission line route shall be selected keeping in view the following:

(1) Routing of a transmission line through protected or reserved forest shall be avoided. In case it is not possible to completely avoid the forests or areas having large trees, keeping in view the overall economy, the route shall be aligned in such a way that cutting of trees is minimum. Routing of a transmission line through National Parks or Wild Life sanctuaries shall also be avoided to the extent possible.

(2) Restricted areas such as civil and military airfields shall be avoided. Care shall also be taken to avoid aircraft landing approaches.

(3) The line routing should avoid large habitations, and densely populated areas to the extent possible.

(4) It shall be ensured that all statutory requirements stipulated under Forest Conservation Act, Wild Life Protection Act, Archeological Survey Act and other Acts/Rules/Laws, as may be applicable, are complied with.

(5) The Owner shall arrange all required consents and approvals including those from Power and Telecommunication Co-ordination Committee (PTCC), and for civil aviation, road, river, rail, canal or power line crossings, way leaves and environmental & forest clearances etc. from the concerned authorities/agencies.

(6) Right of way and way leave clearance shall be arranged by the Owner in accordance with the requirements of construction. Compensation for right of

way & way leaves shall be given as per applicable law, rules & regulations, guidelines and directives of local administrative and revenue authorities.

94. Design and Construction of Transmission Lines

(1) **General**

The transmission lines shall be designed and constructed meeting the requirements mentioned in these regulations, requirements of applicable Indian Standards as well as other rules & regulations as per latest amendments. The Owner shall follow all the prudent utility practices in the design and construction of the transmission lines. Also, the design and construction of the transmission lines shall be such that they perform their intended functions under the License.

(2) **Salient technical particulars and requirements of transmission lines**

(a) Electrical Design Parameters of the Transmission Lines

Table: IV- 1

	Parameter	**66 kV AC**	**132 kV AC**	**220 kV AC**	**400 kV AC**	**765 kV AC**	**500 kV DC**
(i)	Nominal Voltage (kV)	66	132	220	400	765	500
(ii)	Highest System Voltage (kV)	72.5	145	245	420	800	525
(iii)	Full wave Impulse withstand voltage (1.2/50 microsec.) (kVpeak)	325	650	1050	1550	2400	1800
(iv)	Power Frequency Withstand Voltage under dry condition (kVrms)	140	275	460	680	830	-
(v)	Switching Surge Withstand Voltage under Wet condition (kVrms)	-	-	-	1050	1550	1000
(vi)	Minimum Corona Extinction Voltage under Dry condition (kVrms phase to earth)	-	-	156	320	510	550

(vii)	Maximum Radio Interference Voltage at 1 MHz (microvolts) for phase to earth voltage of … kV under Dry condition	-	-	1000 At 156kV	1000 At 267kV	1000 At 510kV	1000 22 kV/cm conductor surface gradient

The above parameters are for transmission lines constructed at altitudes upto 1000m above MSL. For the transmission lines at higher altitudes, basic insulation level, impulse & switching surge withstand voltage requirements shall be kept higher as per relevant standards and practices.

The AC transmission lines shall be transposed, if required depending upon the length of the line, in approximately three equal parts.

(b) Conductor

The conductor of appropriate size shall be selected considering power flow requirements and other system considerations in consultation with neighbouring transmission and generation utilities. For transmission lines of 400 kV or higher voltage class, bundle conductors (minimum two conductors per phase for 400 kV AC and four conductors per phase for 500 kV DC & 765 kV AC) shall be used for satisfactory performance of transmission lines from corona and interference aspects.

The conductors may be of type ACSR, AAAC or other and shall generally conform to relevant IS or IEC standards. Other new technology conductors conforming to International standards and specifications may also be used depending on system requirements.

(c) Earthwire

The earthwire of appropriate size to cater to predicted and design fault currents and lightning shall be used. The earthwire shall be either of galvanized stranded steel (GSS) or alternatively ACSR or AACSR conductor type. Optical fibre ground wires may also be used as earthwire. Other new technology earthwires conforming to international standards and specifications may also be used. Generally, one earthwire shall be used for transmission lines upto 220 kV and two earthwires shall be used for transmission lines of 400 kV and higher voltage classes.

(d) *Towers*

The towers shall be self-supporting lattice steel type and shall be a fully galvanised structure. Alternatively, guyed or pole structure towers may also be used.

Type of towers, design and ruling span, wind & weight spans, extension and truncation provisions etc. shall be selected by the Owner as per prudent utility practices.

Live-metal clearances, mid-span clearance, shielding angle etc. shall be decided as per prudent utility practices following applicable standards and codes and keeping in view electrical system parameters and requirements, line altitude and other service conditions and factors.

Ground clearance shall be as per requirements of Central Electricity Authority (Measures relating to Safety and Electricity Supply) Regulations as and when these are notified by the Authority.

(i) *Design of towers*

The following specify the minimum requirements for design of towers. The Owner may adopt any additional loading or design criteria for ensuring reliability of the line, if so desired and/or deemed necessary.

The towers shall be designed to meet all design requirements and design criteria stipulated in latest revision of relevant IS or IEC standards, considering wind loading corresponding to applicable wind zone for the transmission line as per relevant IS.

The towers shall also be designed for appropriate snow or ice loads, if applicable.

The loads at conductor and earthwire points under different loading conditions viz. reliability conditions (normal condition), security conditions (broken wire condition), safety conditions, anti-cascading condition etc. (as per relevant IS or IEC Standards) considering various combinations of design temperatures, wind and snow loads shall be calculated and tower designs developed accordingly.

Reliability level– 1 corresponding to 50 year return period design loads due to wind as per relevant IS shall be considered for design of towers for transmission lines upto 400 kV. For higher voltage level transmission lines, reliability level–2 corresponding to 150 year return period wind loads shall be considered. Triple and quadruple circuit towers and towers with more than two sub-conductors per phase upto 400 kV shall be designed corresponding to the reliability level– 2 (150 year return period).

Normal towers shall be prototype tested as per relevant IS. It may not be mandatory to have prototype testing of tall river crossing towers and other special towers designed for reliability level– 3 (500 year return period).

(ii) *Materials*

Mild steel and high tensile steel sections of tested quality in conformity with relevant IS shall be generally used in towers and their extensions. Other equivalent grade of structural steel angle sections and plates conforming to International Standards may also be used.

Fasteners, bolts and nuts shall be generally as per relevant IS.

(iii) *Tower fabrication*

Tower fabrication shall generally conform to relevant IS. Tower parts shall be galvanized as per relevant IS.

(iv) *Tower accessories*

Various tower accessories viz. danger plates, number plates, phase plates, circuit plates, anti-climbing devices, bird guards etc. shall be provided conforming to relevant IS**.**

Remedial measures shall be taken by the Owner to put spike type Bird guards on the Upper (tie members), Lower main members and also on Plan bracings in the barrel of the tower at all the cross arm levels to prevent birds from making nests. This measure will also help to improve the performance and availability of the system.

(v) *Earthing*

Each tower shall be earthed such that tower footing resistance does not exceed 10 ohms. Pipe type or Counterpoise type earthing shall be provided in accordance with relevant IS.

(vi) *Aviation requirements and warning signals*

Day and/or night visual aids and markers for denoting transmission line or structures as per requirements of Directorate of Flight Safety or relevant IS or ICAO shall be provided.

(e) *Foundations*

(i) Depending upon soil and site conditions, economy and feasibility of construction at site, appropriate type of foundations (viz. open cast, pile, well or other alternative types) shall be considered for transmission line towers.

(ii) The design of foundations shall be as per applicable Indian Standards and Codes.

Structural design of foundations shall be done by limit state method with minimum overload factor as 1.1.

The minimum factor of safety for design of pile or well foundations shall be 2.5.

(iii) The cement concrete used for the foundations shall be generally as per relevant IS.

(f) *Insulators, Insulator Strings and Hardware Fittings*

(i) Requisite type of suspension and tension insulator strings with disc insulators or long rod insulators offering equivalent performance shall be used. Number of insulators and creepage distance shall be selected based on electrical system parameters and requirements taking into account other factors and conditions viz. line altitude, expected environmental and pollution conditions etc. However, for critical locations with high pollution level, antifog type insulators or polymer insulators may be used for better performance. For voltage levels upto 400kV, specific creepage distance shall be selected from Table: III-6 at clause 47 based on the site requirement. For 765kV, specific creepage distance shall be decided judiciously by the Owner.

(ii) Insulators shall generally conform to relevant IS or IEC standards. Polymer or composite insulators conforming to relevant IEC or other international standards may also be used. Insulators for HVDC lines shall be of anti-fog type having sacrificial zinc sleeve. These shall generally conform to relevant IEC standard.

(iii) Insulator & insulator string rating shall be selected such that :

- Under ultimate design wind loading conditions, the load on insulator string shall not exceed 70 % of its selected rating.

- Under everyday temperature and no wind conditions, the load on insulator string shall not exceed 25% of its selected rating.

(iv) Insulator strings shall be complete with all required hardware fittings. The fittings shall generally conform to relevant IS.

(g) *Accessories for Conductor and Earthwire*

The accessories required for the conductor and earthwire viz. mid-span compression joints, repair sleeve, T-connector, flexible copper bond, vibration dampers, spacer or spacer-dampers, earthwire clamps etc. shall be used as suitable for type and size of conductor and earthwire used for the transmission line. The accessories shall generally conform to relevant IS.

(3) **Transmission line construction**

(a) Construction of a transmission line shall be carried out generally as per relevant IS meeting stipulated requirements and under other latest applicable standards and prudent utility practices.

(b) Crossing of a transmission line with roads or a railway or a river or a power line or a telecommunication line shall be finalized as per applicable rules & regulations specified by the concerned authorities.

(c) Clearances from ground, buildings, roads, power lines, telecommunication lines etc. shall be provided in conformity with Central Electricity Authority (Measures Relating to Safety and Electricity Supply) Regulations as and when these are notified by the Authority.

(d) Clearances from trees, forest clearance etc. shall be provided in accordance with Forest Conservation Act and guidelines issued by Ministry of Environment & Forests.

(e) Normal design span for various voltage level transmission lines shall generally be as follows:

Table: IV- 2

Voltage (kV)	Normal span (metres)
765	400, 450
400	400
220	335, 350, 375
132	315, 325, 335
66	240, 250, 275

(4) **Service conditions**

(a) Equipment and material to be used in the transmission line shall be suitable for satisfactory continuous operation under tropical conditions as specified below:

Table: IV- 3

Maximum ambient temperature (^{0}C)	As per meteorological or climatological data published by Indian Meteorological Department
Minimum ambient temperature (^{0}C)	
Relative humidity (% range)	
Maximum annual rainfall/snowfall (cm)	
Wind zone	As per relevant IS
Maximum wind velocity(m/sec)	
Altitude above mean sea level (metres)	As per actual

(b) For condition assessment of conductors, clamps, connectors, insulators etc., provision for on- line or off- line diagnostic tools and equipment shall be made. On- line tools shall include thermo-vision camera for detection of hot spots, and live line punctured insulator detector. Off-line tools shall include insulation resistance measuring instrument and contact resistance measuring instrument. Other necessary diagnostic equipment may be provided at the discretion of the Owner.

(5) **Cables**

Wherever construction of an overhead transmission line is not possible due to space constraints or right- of- way problems etc., the Owner can use high voltage cables for transmission of power.

(6) **Applicable standards**

BIS or IEC or Equivalent.

PART – B: ELECTRIC LINES (33 KV AND BELOW)

95. General

(1) The lines shall be constructed keeping in view the prime factors of safety as well as electrical and mechanical design considerations.

(2) The Owner shall ensure tie-up arrangements which are necessitated by the proposed installation and which shall be carried out simultaneously by other entities before the new installation is commissioned and connected to the existing power system network. The Owner who is connecting his new installation has to abide by the Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007.

96. Electrical Design Parameters of the Electric Lines

Table: IV- 4

Parameter	**33 kV**	**22 kV**	**11 kV**	**400 V**
Nominal system voltage	33 kV	22 kV	11 kV	400 V
Highest system voltage	36 kV	24 kV	12 kV	440 V
System earthing	Solidly earthed system	Solidly earthed system	Solidly earthed system	Solidly earthed system
Frequency (Hz)	50	50	50	50
Lightning Impulse withstand voltage (kV peak)	170	125	75	60
Power frequency withstand voltage (kV rms) in dry condition	75	50	28	10

The above parameters are for electric lines constructed at altitudes upto 1000 m above mean sea level (MSL). For the electric line at higher altitudes, basic insulation level (BIL), impulse withstand voltage requirements shall be kept higher as per relevant standards/practices.

97. Construction of Electric Lines and Associated Equipment

(1) The system shall be constructed so as to ensure:

(a) Voltage conditions are within permissible levels.

(b) Improvement of reliability and security of power supply.

(c) Improvement in quality of supply.

(d) Adequate capacity for load growth for next 5 years.

(2) Independent feeders shall be provided for essential loads of 5 MVA and above such as water works, hospitals, defence and other sensitive installations.

(3) Separate rural feeders for feeding irrigation load and domestic load shall normally be provided.

(4) Composite lines (i.e. lines having different voltage levels) shall be adopted by the Owner as per requirement.

98. Routing of Electric Lines

(1) The route of the electric line shall be as short as possible.

(2) The routing of an electric line through protected and reserved forest shall be avoided. In case it is not possible to completely avoid the forests or areas having large trees, keeping in view the overall economy, the route shall be aligned in such a way that cutting of trees is minimized.

(3) The routing of an electric line through National Parks and Wild Life Sanctuaries shall be avoided.

(4) Restricted areas such as civil and military airfields shall be avoided. Care shall be taken to avoid aircraft landing approaches.

(5) The 33 kV or 22 kV line route shall be such as to avoid large habitations, and densely populated areas.

(6) The line shall normally avoid rough and difficult country side, and natural obstructions, fruit gardens, lakes, rivers etc.

(7) The electric line shall normally not cross over educational institutes and cremation grounds.

(8) The electric line shall be far off from slaughterhouses to prevent interruptions by bird hits.

(9) The electric line shall be close to a road for approach during construction and ease of maintenance.

(10) Angle points in the route shall be minimized. Railway and road crossings shall be minimum on the line route and in case it is not possible to avoid the same the crossings at right angles shall be preferred but the crossing shall be not less than 60 degrees in any case.

(11) The Owner shall arrange all required consents/approvals including civil aviation, road, river, rail, canal, power line crossings and environmental and forest clearances etc. from the concerned authorities.

(12) The Owner in accordance with the requirements of construction shall arrange right of way and way leave clearance. Compensation for right of way and way leaves shall be given as per applicable law, rules and regulations, guidelines/directives of local administrative/revenue authorities.

99. Design and Construction of Electric Lines

(1) The electric lines shall be designed and constructed complying with the requirements mentioned in this standard, applicable Indian Standards as well as other rules and regulations as per latest amendments. The design and construction of the electric lines shall be such that they perform their intended functions.

(2) Extension of existing lines shall be carried out after ensuring that the limits of voltage variations on the lines are not exceeded.

(3) The reliability and security of supply shall be improved by use of sectionalizers, auto re-closers, ring main units (RMUs) and fault passage indicators as per techno economic considerations.

100. Supports (Poles and Towers)

(1) The supports shall be poles or narrow based lattice towers with fully galvanised structure as per site requirement.

(2) Poles may be used for 33 kV, 22 kV, 11 kV and LT lines (lines below 500 V) as per requirement. The poles shall be pre-cast concrete (PCC) pole, pre-stressed cement concrete (PSCC) pole, rolled steel joist, rail pole or steel tubular pole as required, provided PCC and PSCC poles shall not be used at cut-points and as end poles.

(3) Poles shall conform to relevant IS as the case may be.

(4) Concrete poles shall be preferred in plain areas.

(5) In hilly areas appropriate snow or ice loading shall be considered for design of poles and towers.

(6) For locations involving long spans or higher clearances on account of crossing of power or communication lines or a railway line, specially designed poles/lattice towers may be used.

(7) For angles of deviation of more than 10 degree, double pole structure shall be used.

(8) The height of the pole above the ground level, length of pole below ground and working load shall be decided taking into consideration wind zone, terrain, topography, and the statutory clearances required to be maintained and these shall conform to relevant IS.

101. Line Span

(1) Line span shall be decided taking into consideration topography, wind pressure, type of support, conductor configuration and ultimate tensile strength of conductor.

(2) The span shall be within the range specified by IS.

(3) Uniform span shall be maintained as far as possible between consecutive pole structures.

(4) While constructing a line, if a road crossing occurs at mid span, then a pole shall be placed on one side of the road so as to avoid mid span at the road crossing.

(5) While crossing another power line, the lower voltage line shall be underneath. The lower line shall normally not cross at mid span of the upper line.

(6) While placing poles on high ground, shorter poles can be used while maintaining proper ground clearance at the middle of the span.

(7) Poles shall normally not be placed along the edges or cuts or embankments of creeks and streams.

(8) At all the places where the new line crosses over roads or another existing line, adequately earthed guard wire mesh below the line shall be provided to avoid the conductor of the new line falling over the areas below, in case of any break. In cases where the line passes below an existing line, the guard wire mesh shall be provided above the new line under construction.

102. Erection of Poles

Erection of poles shall be carried out in accordance with the provisions of relevant IS.

103. Factor of Safety

The supports shall be suitable for the wind loads as per relevant IS. The minimum factor of safety for supports shall be as per Central Electricity Authority (Measures Relating to Safety and Electricity Supply), Regulations as and when these are notified by the Authority.

104. Earthing of Poles

(1) All metallic supports shall be permanently and effectively earthed. The earthing arrangement shall conform to relevant IS.

(2) Metal cross arms and insulator pins for PCC and PSCC poles shall be bonded together and normally earthed at every pole for 33 kV or 22 kV or 11 kV lines and at every 5th pole for lines below 500 volts.

(3) The support on each side of a road crossing, railway crossing or river crossing shall be earthed.

(4) Normally coil earthing shall be provided except for locations involving railways, telegraph line, power line crossings and special structures where pipe/rod type earthing shall be provided. Whenever the electric lines pass close to a well or a permanently moist place, an earth should be provided in the well or the marshy place and connected to the electric line pole.

(5) All steel poles on which switches, transformers, fuses etc. are mounted shall be earthed.

(6) All poles above 650 volts, irrespective of inhabited areas, shall be earthed. For poles below 650 V guarding with continuous earth-wire shall be provided invariably, connected to earth at three equidistant points in one km.

105. Stay Arrangements

(1) To prevent tilting of a pole from its normal position due to abnormal wind pressure and deviation of alignment, the pole shall be kept in position by stays. The stays shall be provided at:

(a) Angle locations

(b) Dead end locations

(c) Tee off points

(d) Steep gradient locations

(e) Cut – point

(f) Along the straight run at minimum 2 locations in 1 km

(2) Galvanized iron stay wires and stay rods of adequate size shall be used. The individual wire used to form "stranded stay-wire" shall have a minimum tensile strength of 700 N/sq mm as per IS. For double pole structure, four stays along the line, two in each direction and two stays along the bisection of the angle of deviation or as required depending on the angle of deviation shall be provided.

(3) When two or more stays are provided on the same pole, each stay shall be grouted entirely separate from the other.

(4) The angle between the pole and stay wire shall be about 45 degrees and in no case it shall be less than 30 degrees.

(5) Stays shall be anchored either by providing base plates, angle iron or rail.

(6) Stay wires shall be connected to the pole with a Porcelain Guy Strain Insulator. The standard Guy Strain insulators shall be as per relevant IS. The Porcelain insulator shall be inserted in the stay wire at a height of minimum 3 m vertically above the ground level. The strain insulators shall be free from defects, thoroughly vitrified and smoothly glazed.

(7) Wooden insulators shall not be used for stay/guy wire.

106. Protective Guard

Guard wire shall be used where an overhead line crosses or is in proximity to any telecommunication line or any other overhead line and in populated localities. Every guard wire shall be connected to earth wherever its electrical continuity is broken. The minimum factor of safety for stay wires, guard and bearer wires shall not be less than 2.5 based on ultimate strength of the wire.

107. Anti Climbing Devices

Anti climbing devices shall be provided on the supports. For this purpose barbed wire conforming to relevant IS for a vertical distance of 30 to 40 cm. at a height of 3.5 to 4 meters from ground level or clamps with protruding spikes at a height of 3 to 4 meter shall be used.

108. Danger Plates

Danger Plates shall be provided on electric lines in accordance with Central Electricity Authority (Measures Relating to Safety and Electricity Supply), Regulations as and when these are notified by the Authority.

109. Insulators, Insulator Strings and Hardware Fittings

(1) Pin insulators shall generally be used on the straight stretch of a line. The pin insulators shall conform to relevant IS. The pin insulators may be used on lines up to 33 kV voltage level. The pin insulator shall consist of a single piece of porcelain mounted rigidly on a supporting structure on a pin.

(2) Shackle insulators shall be used in lines below 500 volts and these shall conform to IS. Strap type fittings shall be used for a dead end location, while U-clamp fittings shall be used at tangent locations.

(3) Requisite type of suspension and tension insulator strings with disc insulators or long rod insulators offering equivalent performance shall be used on 33 kV or 22 kV or 11 kV lines. The number of insulators, and creepage distance shall be selected based on electrical system parameters taking into account altitude of site, expected environmental and pollution conditions etc.

(4) Disc insulators shall conform to relevant IS. Polymer/composite insulators conforming to relevant IEC/other International Standards may also be used.

(5) Disc insulators shall be of Ball and Socket type or Tongue and Clevis type.

(6) Insulator strings shall be complete with all required hardware fittings. The fittings shall conform to relevant IS.

(7) Insulator and insulator string rating shall be selected such that:

(a) Under ultimate design wind / snow loading conditions, the load on insulator string shall not exceed 70% of its selected rating.

(b) Under everyday temperature and no wind / snow conditions, the load on the insulator string shall not exceed 25% of its selected rating.

(8) The insulation shall be designed to avoid excessive concentration of electrical stresses in any section or across leakage surfaces.

110. Cross-Arms

Cross arms shall be provided in accordance with the requirement. In case, they are made of mild steel, the cross-arms and the clamps shall be hot dipped galvanized conforming to relevant IS, after completion of fabrication. Welding at site should be avoided as far as possible, in case welding becomes necessary, the joint shall be covered with cold galvanizing paint.

111. Conductor

(1) The size of the conductor shall depend upon the voltage regulation, factor of safety, power to be transmitted, length of line, line voltage and mechanical strength desired.

(2) Steel Reinforced Aluminum Conductors (ACSR) or equivalent All Aluminum Alloy Conductors (AAAC), AAC (All Aluminum Conductor), AACSR (Aluminum Alloy Conductor Steel Reinforced) shall be used according to requirement.

(3) Required accessories for conductor and earthwire viz. mid-span compression joints, repair sleeve, T-connector, flexible copper bond, vibration dampers, spacer/spacer-dampers, earthwire clamps etc. shall conform to relevant IS.

(4) The configuration of conductors on the line can be triangular, horizontal or vertical depending upon the voltage level of the lines, terrain, right of way and clearances to be maintained. In case clearance from a building is difficult to secure, vertical arrangements of the conductor shall be adopted.

(5) The installation of the conductor on the poles shall be carried out in accordance with the methodology given in relevant IS.

(6) Suitable insulating paint shall preferably be provided on bare conductors in coastal areas to prevent corrosion as well as in power theft prone areas.

112. LT Spacers

To avoid clashing and accidental mutual touching of bare overhead conductors on LT lines, spacers, which can be either spiral or composite shall be provided in between conductors at appropriate locations in different spans (particularly for lines having longer spans or lines having large sags encountering high winds).

113. Cables

(1) Underground cables or aerial bunched cables (ABC) of adequate rating can also be used for supplying power. Cables shall conform to relevant Indian Standards.

(2) PVC cables shall not be used in systems other than LT system.

(3) Aerial bunched cables shall be used in the theft and accident-prone areas.

(4) Direct burying of underground cables shall not be adopted except where cables enter and take off from a trench.

(5) The underground cables shall be segregated by running in separate trenches or on separate racks.

(6) The cable trenches shall be properly sloped so as to drain freely any water, which may enter.

(7) Cable trenches shall not be run through oil rooms.

(8) Cables shall not be laid directly on trench floor.

(9) Adequate number of spare cores shall be included in all control cables.

114. Service Line

(1) The service line shall be provided with insulated conductor, armoured cable or underground cable. The service line shall have adequate margin to take care of load growth for at least five years.

(2) Over head service connection shall be provided either through independent service connection or through LV box. No tapping of service line shall be permitted for supplying power to any other consumer. Feeder pillar-box shall be used for providing under ground service connection through cable to more than three or four consumers.

(3) The supplier shall provide and maintain on the consumer's premises for the consumer's use a suitable earthed terminal in an accessible position at or near the point of commencement of supply in accordance with Central Electricity Authority (Measures Relating to Safety and Electricity Supply), Regulations as and when these are notified by the Authority.

(4) The meters for the consumer connections shall be provided in accordance with the Central Electricity Authority (Installation and Operation of Meters) Regulations, 2006.

115. Lightning Protection

(1) The surge arresters (SAs) shall be placed at the terminal points of the lines and also at the junction points of cables and bare overhead conductor lines.

(2) For 33 kV, 22 kV and 11 kV lines, surge arresters having rated voltage of 30 kV (rms), 20 kV (rms) and 9 kV (rms) and discharge current rating of 10 kA, 7.5 kA and 5 kA, complying with relevant IS, shall be used respectively.

(3) The earthwire of appropriate size to take care of predicted/design fault currents and lightning shall be used. The earth wire shall be either of galvanized stranded steel (GSS) or alternatively ACSR/AACSR conductor.

(4) The earthing lead for the surge arrester shall not pass through any iron or steel pipe, but shall be taken directly to a separate earth electrode.

116. Protection of 33 kV, 22 kV, 11 kV and LT System

(1) The protection scheme shall be finalized by the Owner based on prudent utility practice.

(2) An earth leakage protective device shall be provided at consumer premises as per requirement of Central Electricity Authority (Measures Relating to Safety and Electricity Supply), Regulations as and when these are notified by the Authority.

Glossary

AAAC	All Aluminium Alloy Conductor
AAC	All Aluminium Conductor
AACSR	Aluminium Alloy Conductor Steel Reinforced
ABC	Aerial Bunched Cables
AC	Alternating Current
AC-PLCC	AC – Power Line Carrier Communication
ACSR	Aluminium Conductor Steel Reinforced
AIS	Air Insulated Switchgear/ Sub-station
AMF	Automatic Mains Failure
ANSI	American National Standards Institute
API	American Petroleum Institute
ARC	Auto Reserve Closure
ASME	American Society of Mechanical Engineers
ASTM	American Society of Testing and Materials
ATT	Automatic Turbine Testing
ATRS	Automatic Turbine Run up System
AVR	Automatic Voltage Regulation
AWS	American Welding Society
AWWA	American Water Works Association
BFP	Boiler Feed Pump
BIS	Bureau of Indian standards
BMCR	Boiler Maximum Continuous Rating
BMS	Burner Management System
BMS	Building Management System
BS	British Standard
CACA	Closed Air Circuit Air Cooled
CACW	Closed Air Water Cooled
CB	Circuit Breaker
CCGT	Combined Cycle Gas Turbine
CCS	Computerised Control System
CEP	Condensate Extraction Pump
CERC	Central Electricity Regulatory Commission
COV	Continuous Operating Voltage
CPCB	Central Pollution Control Board
CRGO	Cold Rolled Grain Oriented
CSP	Completely Self Protected
CT	Current Transformer
CTU	Central Transmission Utility
CVT	Capacitance Voltage Transformer
CW	Cooling Water

DAS	Data Acquisition System
DB	Distribution Board
DC	Direct Current
DCDB	DC Distribution Board
DCS	Digital Control System
DDCMIS	Distributed Digital Control, Monitoring and Information System
DG	Diesel Generator
DIN	Deutsches Institut fur Normung
DM	Demineralisation
DOV	Dynamic Over Voltage
DP	Double Pole
DPS	Dynamic Performance Study
DSS	Distribution Sub Station
E/F	Earth Fault
EHG	Electro-hydraulic Governing
EHV	Extra High Voltage
EOT	Electric Overhead Travelling
ESP	Electro Static Precipitator
FBC	Fluidized Bed Combustion
FD	Forced Draft
FRLS	Flame Retardant Low Smoke
FS	Fire Survival
FSSS	Furnace Safeguard Supervisory System
GCB	Generator Circuit Breaker
GIS	Gas Insulated Switchgear/ Sub-station
GPS	Global Positioning System
GSS	Galvanized Stranded Steel
HE	Hydroelectric
HEI	Heat Exchanger Institute
HHV	High Heat Value
HFL	High Flood Level
HFO	Heavy Fuel Oil
HIS	Hydraulic Institute Standard
HMIS	Human Machine Interface System
HP	High Pressure
HPS	Heavy Petroleum Stock
HRSG	Heat Recovery Steam Generator
HSD	High Speed Diesel
HT	High Tension
HV	High Voltage

HVDC	High Voltage Direct Current
HV W	High Velocity Water
IBR	Indian Boiler Regulations
ICAO	International Civil Aviation Organisation
ICT	Interconnecting Transformer
ID	Induced Draft
IDMT	Inverse Definite Minimum Time
IEC	International Electro-technical Commission
IED	Intelligent Electronic Device
IEEE	Institute of Electrical and Electronics Engineers
IS	Indian Standard
ISO	International Organisation for Standardisation
JIS	Japanese Industrial Standards
KV	Kilo Volt
KWH	Kilo Watt Hour
LAN	Local Area Network
LDC	Load Despatch Centre
LDO	Light Diesel Oil
LFC	Load Frequency Controller
LP	Low Pressure
LT	Low Tension
LV	Low Voltage
LVS	Large Video Screen
MCB	Miniature Circuit Breaker
MCC	Motor Control Centre
MCCB	Moulded Case Circuit Breaker
MCR	Maximum Continuous Rating
MFT	Master Fuel Trip
MGR	Merry-Go-Round
MIV	Main Inlet Valve
MKS	Metre Kilogram Second
MMI	Man Machine Interface
MOE&F	Ministry of Environment and Forest
MOG	Magnetic Oil Gauge
MOP	Main Oil Pump
MOV	Metal Oxide Varistor
MS	Mild Steel
MSL	Mean Sea Level
MVA	Mega Volt Ampere

MW	Mega Watt
NEC	National Electric Code
NEMA	National Electrical Manufacturers' Association
NFPA	National Fire Protection Association
NPSH	Net Positive Suction Head
O/C	Over Current
OCTC	Off Circuit Tap Changer
ODWF	Oil Draft Water Forced
OFAF	Oil Forced Air Forced
OFWF	Oil Forced Water Forced
OLTC	On Load Tap Changer
O&M	Operation & Maintenance
ONAF	Oil Natural Air Forced
ONAN	Oil Natural Air Natural
OPU	Oil Pressure Unit
OSHA	Occupational Safety and Health Administration
OSR	Oil Surge Relay
OTI	Oil Temperature Indicator
PA	Primary Air/ Public Address
PCC	Power Control Center
PCC	Pre Cast Concrete
PDA	Partial Discharge Analyzer
PDM	Partial Discharge Monitoring
PIR	Pre-insertion Resistor
PIV	Peak Inverse Voltage
PLC	Programmable Logic Controller
PLCC	Power Line Carrier Communication
PRD	Pressure Relief Device
PRV	Pressure Relief Valve
PSCC	Pre Stressed Cement Concrete
PSS	Power System Stabilizer
PTCC	Power and Telecommunication Co-ordination Committee
PVC	Poly Vinyl Chloride
RCC	Reinforced Cement Concrete
REF	Restricted Earth Fault
RMS	Root Mean Square
RMU	Ring Main Unit
RRRV	Rate of Rise of Recovery Voltage
RSJ	Roller Steel Joist
RTD	Resistance Temperature Detector
RTDS	Real Time Digital Simulator

SA	Surge Arrester
SAVT	Surge Arrester and Voltage Transformer
SCADA	Supervisory Control and Data Acquisition System
SCAPH	Steam coil Air Pre-heater
SI	System International
SOE	Sequence of Event
SPCB	State Pollution Control Board
SPM	Suspended Particulate Matter
SSB	Station Service Board
SSC	Submerged Scrapper Conveyor
SSR	Sub Synchronous Resonance
STATCOM	Static Compensator
STU	State Transmission Utility
SVC	Static VAR Compensator
SWAS	Steam and Water Analysis System
TAC	Tariff Advisory Committee (established under Insurance Act 1938)
TCSC	Thyristor Controlled Series Capacitor
TEFC	Totally Enclosed Fan Cooled
TEMA	Tubular Exchanger Manufacturers' Association
TETV	Totally Enclosed Tube Ventilated
TG	Turbine- Generator
TRV	Transient Recovery Voltage
TSE	Time Synchronising Equipment
UAB	Unit Auxiliary Board
UAT	Unit Auxiliary Transformer
UCB	Unit Control Board
UPS	Un-interrupted Power Supply
VDE	VDE association for Electrical, Electronic and Information Technologies
VESDA	Very Early Smoke Detector Acquisition
VT	Voltage Transformer
VVVF	Variable Voltage Variable Frequency
VWO	Valves Wide Open
WTI	Winding Temperature Indicator
XLPE	Cross Linked Poly Ethylene